1985-1987

UNIVERSITY OF LOWELL GRADUATE SCHOOL CATALOGUE

1985-1987
GRADUATE SCHOOL CATALOG
UNIVERSITY OF LOWELL

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UNIVERSITY OF LOWELL

Lowell, Massachusetts

THE GRADUATE SCHOOL CATALOG
1985-1987

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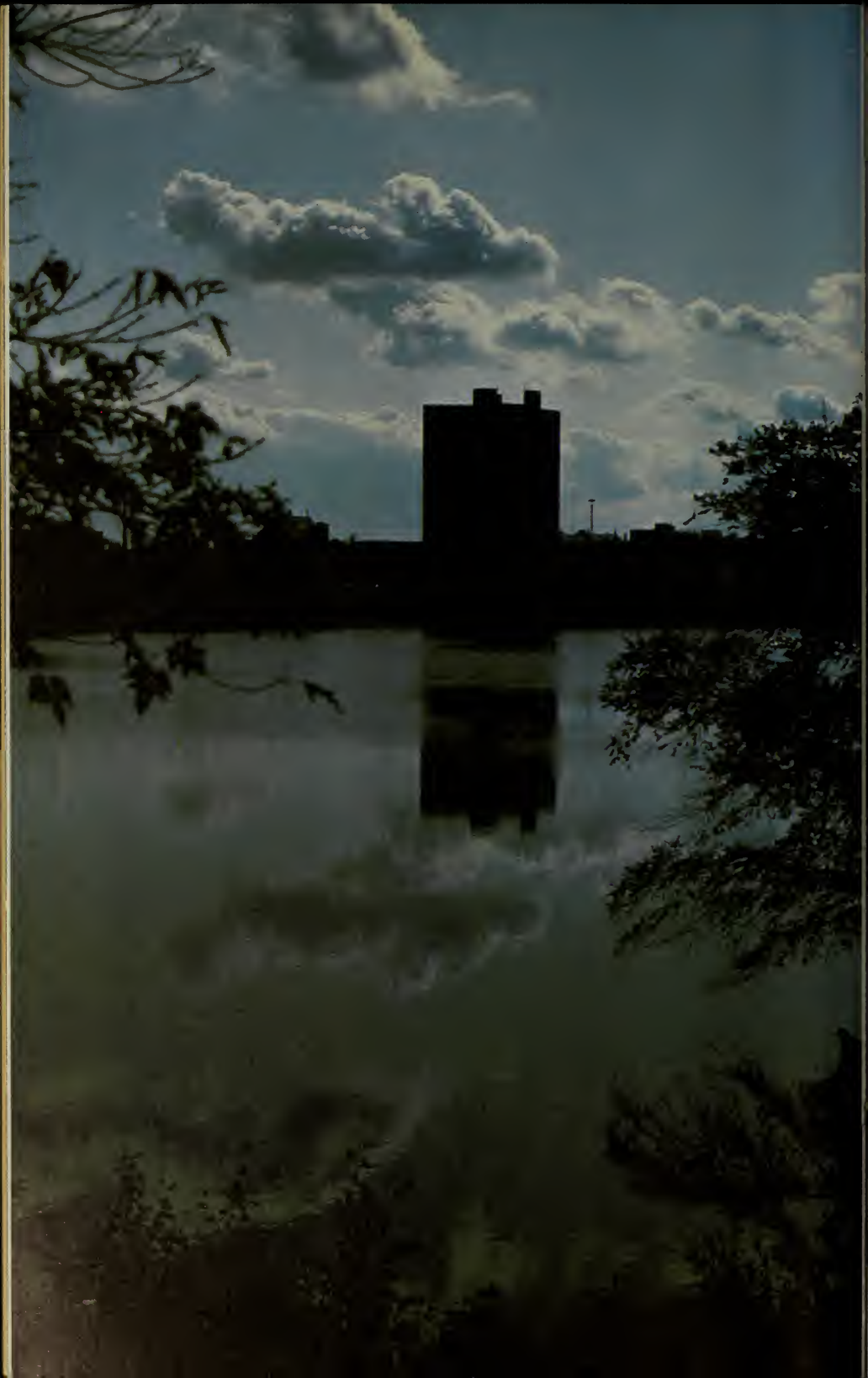


UNIVERSITY OF LOWELL

One University Avenue
Lowell, Massachusetts 01854
Telephone: (617) 452-5000

Established in 1975 by a merger of
Lowell Technological Institute, established 1895
and
Lowell State College, established 1894

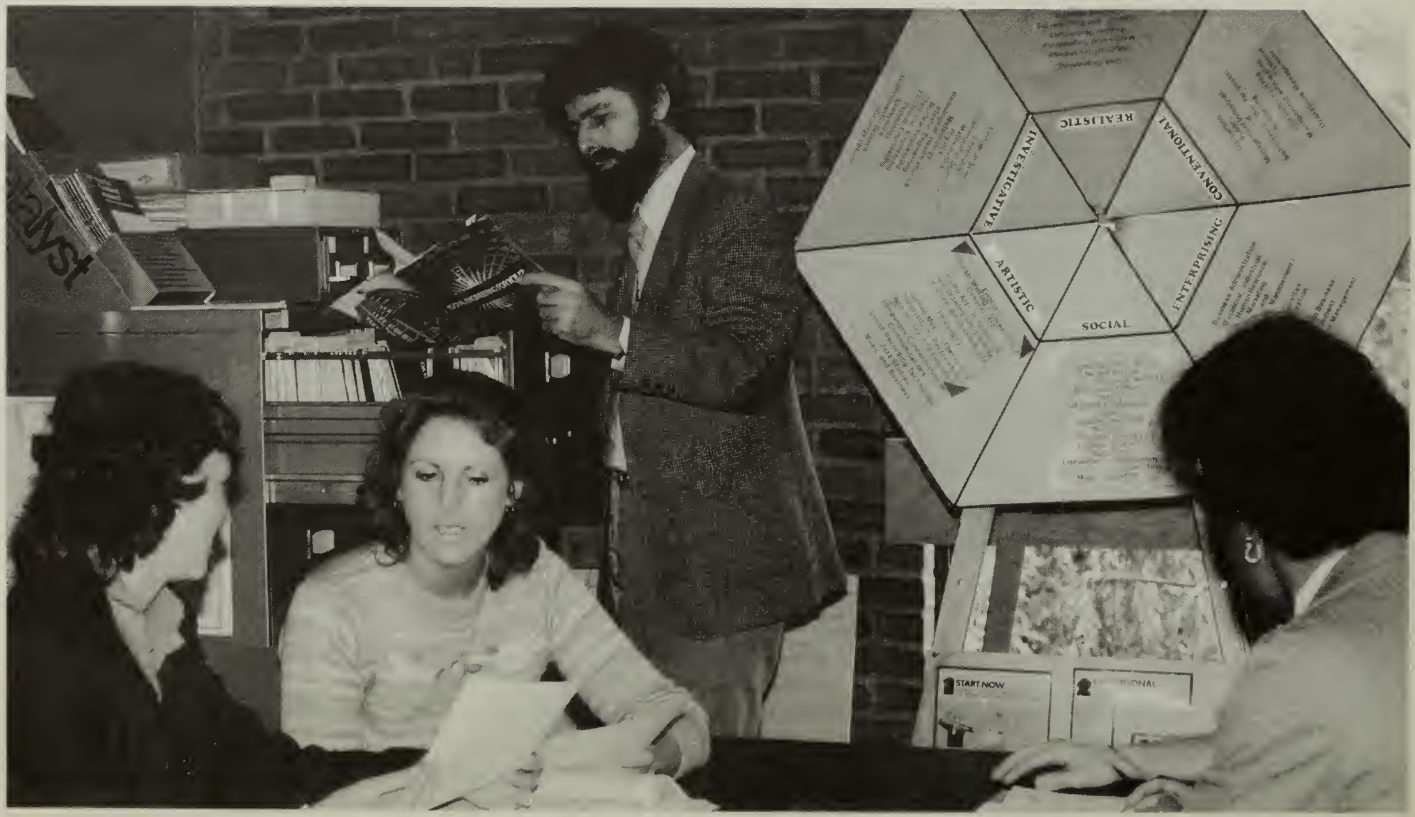
ACCREDITATION AND PROFESSIONAL MEMBERSHIPS

The University of Lowell is an accredited member of the New England Association of Schools and Colleges. Professional programs are also accredited by the following national associations:

American Chemical Society
Accreditation Board for Engineering and Technology (Chemical Engineering, Civil Engineering, Electrical Engineering, Energy Engineering, Mechanical Engineering and Plastics Engineering)
National Accrediting Agency for Clinical Laboratory Sciences
National Council for the Accreditation of Teacher Education (Elementary Education, Music Education, and Secondary Education)
National League for Nursing

The University of Lowell is also a member in good standing of the following associations of higher education:

American Assembly of Collegiate Schools of Business
American Association of Colleges for Teacher Education
American Society for Engineering Education
Association for Gerontology in Higher Education
American Association of Colleges of Nursing
American Council on Education
Association for State Colleges and Universities
College Entrance Examination Board
Council of Graduate Schools in the United States
Interstate Certification Compact
National Association of Summer Sessions
National University Extension Association
New England Board of Higher Education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PROGRAMS OFFERED

The University of Lowell Graduate School offers graduate programs in the following areas:

Doctor of Philosophy (Ph.D.)

Chemistry - Polymer Science and Plastics Engineering Option, Environmental Studies Option, and Biochemistry Option

Physics - Energy Engineering Option, Applied Mechanics Option, Radiological Sciences Option, Computational Physics Option

Doctor of Science (Sc.D.)

Computer Science

Doctor of Education (Ed.D.)

Education (Planning Stage)

Doctor of Engineering (Eng.D.)

Electrical Engineering
Mechanical Engineering
Plastics Engineering

Certificate of Advanced Graduate Study (C.A.G.S.)

Reading and Language

Master of Arts (M.A.)

Community and Social Psychology
Criminal Justice (Planning Stage)

Master of Science (M.S.)

Biological Sciences
Chemistry
Computer Science
Health Services Administration

Mathematics - Statistics and Operations Research Option, Computer Option, Mathematics for Teachers Option, Applied Mathematics Option

Nursing - Administration of Nursing Services Option, Gerontological Nursing Option, Family and Community Health Nursing Option

Physics
Polymer Science
Radiological Sciences

Master of Science in Engineering (M.S. Eng.)

Chemical Engineering
Civil Engineering
Computer Engineering
Electrical Engineering
Energy Engineering (Fission, Fusion, Solar, Geothermal)
Environmental Studies
Mechanical Engineering
Paper Engineering
Plastics
Plastics Engineering - Coatings and Adhesives Option, Synthetic Fibers Option
Systems Engineering

Master of Education

Curriculum and Instruction - Initial Certification Option, Technology and Learning Environments Option, Computer Education, Economics Education, Experienced Teachers Option, Human Services Option (non-health services related)
Educational Administration
Reading and Language

Master of Music (M.M.)

Performance (Conducting Option)
Music Education
Musicology
Music Theory/Composition

Master of Business Administration (M.B.A.)

Master of Management Science in Engineering (M.M.S. Eng.)

Manufacturing Engineering
Construction Engineering

UNIVERSITY PROFILE

History

The University of Lowell was established by Chapter 1175, General Laws of the Commonwealth of Massachusetts, through a merger of Lowell State College and Lowell Technological Institute. These two institutions were established in the last decade of the 19th century as single-purpose institutions and were charged with providing instruction in those theories and practical arts which were most suitable to the teaching profession and the textile industry. Lowell State College was chartered by the General Court of the Commonwealth on January 6, 1894 as a teacher-training institution and was assigned the responsibility for providing "the most thorough knowledge of the branches of learning required to be taught in schools, the best methods of teaching these branches, and right mental training." In 1932, the institution was made a four-year college and was granted the right to confer baccalaureate degrees. In 1960, the college became a multi-purpose institution by initiating non-teaching programs in the liberal arts. During the next decade and a half the college continuously extended its mission and curriculum offerings at both the graduate and undergraduate levels and was authorized to offer degree programs in education, the health professions, the liberal arts, sciences, and music.

From the time of its origin in 1895 as a proprietary textile school, Lowell Technological Institute has provided educational programs of an applied and practical nature. "Science and art will be taught," the original prospectus pointed out, "with a view to industrial and commercial application" and for "the purpose of improving any special trade or of introducing new branches of industry." The control of the school was transferred to the Commonwealth in 1918, and in 1928 it was granted collegiate status. In 1953, it became a multi-purpose technological institute. During the last two decades, the institute phased out its textile curricula, extended its curriculum offerings in engineering and technology, the pure and applied sciences, business administration and industrial management. In 1965, Lowell Technological Institute received authorization to offer degrees through the doctorate level.

The merger of Lowell State College and Lowell Technological Institute brought together two multi-purpose institutions of differing character and orientation and made possible the creation of a comprehensive university whose strengths and resources are manifestly greater than those possessed by the two separate institutions. The University of Lowell's graduate students account for approximately 2,200 of the 16,500 students enrolled, and the graduate faculty numbers approximately 250 of the 461 members of the University's teaching staff. The combined institutions have organized diversified graduate programs in the fields of Business Adminsitration, Education, Engineering, Health Professions, Music, Pure and Applied Sciences and Psychology.

Purpose of the University

Recognizing its responsibility as a publicly supported institution of higher education, the University of Lowell seeks to discover, integrate, and trans-

mit knowledge to meet the economic, professional, and cultural needs of the Commonwealth. To these ends, the University offers undergraduate and graduate degree programs in business, education, engineering and technology, nursing, liberal arts, music, and the pure and applied sciences. The University maintains a wide range of continuing education programs for those individuals who cannot attend classes on a full-time basis because of age, family responsibilities, or economic constraints and for those who seek continuing personal and professional development. The University also provides special business, industrial, health, scientific, and educational seminars and training programs in cooperation with both public and private sectors. Through these educational programs, the University strives to develop individual capacities for rational analysis and effective decision-making and to create a basic understanding of our cultural and scientific heritage. Finally, the University has a special mission to continue the positive implementation of Equal Opportunity/Affirmative Action, Title IX, thereby ensuring that all students and employees, and in particular, minorities, veterans, women and handicapped persons are guaranteed the benefits of a just and equitable educational system.

Mission of the Graduate School

The mission of the Graduate School at the University of Lowell is to provide a fertile and stimulating environment for teaching, learning, research, dissemination of professional skills, and promotion of the pursuit of knowledge. To this end, the Graduate School encourages the assemblage of scholars, scientists, and artists under whose direction graduate students can pursue advanced studies and carry out research activities. The quality of the Graduate Faculty involved in these programs is the most important factor in the establishment of excellence. In an endeavor to accomplish the mission of the Graduate School, each professor aspires to be a creative and skillful teacher.

The Graduate School recognizes its responsibility as a publicly-supported institution of higher education to develop in students competence and motivation to work toward the realization of individual and community potential. The central purpose of the University is to enhance the quality of life in our society through knowledge. The role of the Graduate School in this overall objective is to train individuals with superior potential in the expertise of their chosen profession and to advance the frontiers of knowledge through research.

Location

The University of Lowell is located 25 miles northwest of Boston and is situated on the northwestern periphery of the City of Lowell. The two major campuses lie on opposite sides of the Merrimack River, the power source which gave rise to America's first industrial city. The North Campus is the primary location for the Sciences, Engineering, and Management and is a short distance across the river from the Research Foundation and Fox Student Union Building. The latter facility is the center for student campus life, including many activities accessible to graduate students. The South Campus is situated on a bend of the Merrimack River approximately one

mile upstream from the North Campus and occupies an elevated site midway between the mouths of the historic Middlesex and Pawtucket Canals. The Colleges of Education, Liberal Arts, Music and Health Professions are located on the South Campus. The physical area of the University campuses includes 29 buildings on 105 acres of land. The campuses are easily accessible from US Route 3 and Interstate 495, by train from Boston (Massachusetts Bay Transportation Authority), and by local and interstate bus lines (Massachusetts Bay Transportation Authority, Continental, and Vermont Transit).

In addition to being the home of the University of Lowell, Lowell is a city rich in heritage. Due to its prime location on the Merrimack River, it became the first great industrial city in the United States. Different immigrant groups migrated to Lowell to work in the mills that were built along the river. Today, the descendants of these varied ethnic groups make up much of Lowell's population. The city is the site of an Urban National Park, illustrating Lowell's industrial and multi-ethnic history.

UNIVERSITY LIBRARIES

The University libraries consist of the Alumni/Lydon Library and the O'Leary Library. The O'Leary Library has holdings in the humanities, social sciences, education and music. The Alumni/Lydon Library specializes in materials in science, technology and business. The special collections area of the University libraries includes rare books and artifacts relating to the history of the City of Lowell. The reference department provides interlibrary loan services, computer and manual literature searches, special bibliographic instruction and ready reference service. The University libraries have also been designated as a United Stated Government depository for unclassified documents. Information and handbooks about the University libraries are available at the circulation and reference desks of the libraries.

Media Services, a division of the University libraries, provides presentation, production and consultation related to instructional media.

The O'Leary Library incorporates a media center that can accommodate over 230 students in five instructional and presentation areas. The Alumni/Lydon Library can accommodate over over 140 students in two instructional and presentation areas. The combined collection includes 450 films and video tapes, over 4000 scores and over 5000 records and tapes of classical, jazz, folk, rock and other musical forms.

Media professionals are available on each campus to assist with media and music listening needs at the University. For further information and assistance, call or write the University libraries.

Computer Resources

The University of Lowell Computer Center houses 2 Control Data Corporation Cyber 180-825's mainframes (with 4 gigabytes of on-line storage, 500 terminal ports including 40 intelligent graphics stations) and a Data General MV 8000 supermini computer (with 40 ports accessible via a broadband network).

The College of Engineering houses a DEC VAX II/780, II/785, microVAX II, and a dozen minicomputers (with 100 terminals, most of which have graphics capabilities). The College also possesses assorted microprocessors, a Computervision Designer V CAD/CAM system with five work stations (three color and two monochrome), and a Hewlett-Packard HP 1000 dedicated to real-time structural analysis. A variety of application software packages are available such as ADINA, ANSYS, SAP4, FEAP, ACSL and MOLDFLOW.

A network of 41 Apollo DOMAIN nodes are being installed to support design and analysis needs in Electrical and Mechanical Engineering, Computer Science and the Center for Productivity Enhancement. (DN300, 320, 550, 460 and 660 nodes are included in the network).

The Computer Science Department of the College of Pure and Applied Science possesses a DEC VAX II/780, 2 – II/750's, II/730, 2 Data General MV 4000's, Symbolics 3600, 2 microVAX II's a Ridge 32, and Automatix Autovision IV and a variety of microcomputers. Two PDP 11/60's, a PDP 11/23, and four PDP 11/03's also are located in the College, providing access to 32 ports.

4 Wang VS WP systems with 36 work stations are available to the general University community. Three DEC PDP 11/60's and 2 microVAX II's service the word processing needs in the Colleges of Management Science, Health Professions, Liberal Arts, and Education. The College of Management Science also houses a DEC PDP 11/70 with a full assortment of peripherals and software tools. University software systems include assemblers, FORTRAN, COBOL, BASIC, ALGOL, ADA, MODULE-2, APL, Pascal and Data Base Management Systems. (Ingres Infocin, Oracle). Application packages inlcude IMSL, SPSS, TSP, and ASCL, SIMSCRIPT, NAG. In addition, the University library system is fully computerized.

Durgin Hall

In 1976 the University opend this major complex for the performance, practice and teaching of music. Beautifully situated on the banks of the Merrimack River, Durgin Hall contains a concert hall with seating for over one thousand and features an acoustical shell on the stage, an orchestra pit which can be raised and lowered, and a lighting console of sufficient flexibility to permit production of any type of concert from chamber music to opera or any type of theater from musicals to classical drama. The recital hall, which seats 250, is ideal for student and faculty recitals and houses a Schlicker tracker organ of eleven ranks. Seventy-two practice cubicals, twelve classrooms and sixteen teaching studios, two recording studios, two

electronic piano laboratories and an electronic music studio provide basic facilities to study, teach, and perform.

Energy Center

The University of Lowell Pinanski Energy Center is a modern educational and research facility. The central complex of the Center is a three-story building devoted to research and instruction in various fields of science and engineering. The two major facilities of the Center include a 1 Mw pool-type research reactor and a 5.5 Mev van de Graaf accelerator. The reactor is sued for graduate research through activation analysis of various environmental, geologic and industrial process samples, and through studies of radiological partical behavior; it is also used for training and education in the fields of engineering, radiochemistry, radiation protection, and instrumentation, to name a few. The accelerator is used mainly for graduate research in nuclear structure and material engineering, particularly as applied to gathering data for fast breeder reactor design. A solar collector-testing facility exists on the roof of the Energy Center, and other solar equipment is used in the formal solar engineering courses. Although financed by the Commonwealth mainly to serve the curricula of the University, the facilities are available by arrangement to other Massachusetts colleges and universities, and to industrial firms for a variety of research and educational purposes. The Center is also equipped with an advanced machine shop, and an assortment of teaching and research laboratories.

Research Foundation

The Research Foundation was established in 1950 as a not-for-profit organization which operates for income derived from research funded by private industry, foundations, and government agencies. The foundation contains major support facilities for faculty and student research projects, and provides a mechanism for the administration and fiscal management of all academic grants and contracts. Two auxilliary enterprises, the Meteorology and Testing Divisions, help to defray the overhead costs of the facility. Meteorology services are provided to assist industry and government through the repair and calibration of electronic test equipment with traceablility to the National Bureau of Standards. This service is available from the Foundation or its fully equipped mobile laboratory. Also based at the Foundation are the Center for Atmospheric Research and the Center for Tropical Diseases.

As part of its close cooperation with the University, the Research Foundation employs both graduate and undergraduate students from the University on a part-time basis. These students gain practical experience which often becomes part of an advanced degree program. In addition to the research which is carried out on campus, research projects also have been conducted in Thailand, Belgium, Greece, Italy, Germany, Algeria and other parts of the world where the Unversity is becoming known for its significant expertise. For further information, contact Mr. Edward F. Miller, Jr., Executive Director, University of Lowell Research Foundation, 450 Aiken Street, Lowell, Massachusetts 01854, telephone (617) 458-2508.

Continuing Education and Summer School

The Division of Continuing Education provides many opportunities for graduate study, from evening courses in degree programs to summer day workshops and special projects.

Graduate level courses are scheduled in conjunction with programs in music, plastics, engineering, education, nursing and the sciences. Additionally, non-credit courses, workshops, conferences, and special projects may be arranged through Continuing Education.

Evening credit courses normally meet once per week during the 15-week fall and spring sessions. Summer courses (May through August) are arranged flexibly, day or evening, to accommodate needs.

All Continuing Education programs are self-supporting and are conducted at no cost to the Commonwealth. Complete information is available in the Graduate School or the Continuing Education Office.

The University of Lowell is a member of the National University Continuing Education Association (NUCEA) and the National Association of Summer Schools (NASS).

Housing

The Graduate School has four annex units for year-round residence of graduate students. The facilities are scheduled for expansion in the near future to meet the incoming student demands.

Married student housing is available and is located within a ten-minute walk from the North Campus. One- and two-bedroom apartments are available. The rental cost of these apartments includes a refrigerator, stove, dishwasher and air conditioner.

Because of the great demand on the limited resources available, the above facilities can be rented only on a first-come first-served basis. Interested students should fill out an application at the Graduate School as early as possible.

Other housing arrangements may be made by obtaining a list of apartments and rooms for rent from the University Housing Office. The University does not sanction or otherwise endorse any housing off the campus, and accepts no responsibility for student residences other than University-supervised facilities. For further information concerning University housing, call or write the Graduate School Office.

Health Services

The University Health Office is open 8:00 am to 4:30 pm, Monday through Friday. It is located at 30 Standish Street behind the Alumni/Lydon Library, (extension 2280). A first aid station is also maintained on the lower level of Mahoney Hall and is open between the hours of 8:00 am and 11:30 am, Monday through Friday.

Services include first aid, care of minor illnesses, monitoring of chronic illness and health counseling. Services are provided by a physician, nurse practitioner, or registered nurse with referrals to and consultation with specialists, as appropriate.

Medications prescribed by the Health Service must be filled at a pharmacy of the student's choice.

A limited amount of laboratory tests can be performed at the Health Services Office. All other tests are referred to area laboratories, and the student is responsible for fees incurred.

When the Health Service is closed, medical service may be obtained at one of the three local hospitals.

Graduate Student Association

The purpose of the Graduate Student Association is to enhance the academic, social, and economic advancement of all graduate students, to represent the graduate student body in University affairs, to establish closer interdepartmental relations among graduate students, faculty, and the administration, and to promote the common interests and better communication among graduate students and with other components of the university community. All graduate students who pay the Graduate Activity Fee are members of this organization. All colleges offering graduate programs are represented in its governing bodies.

Veterans

The University of Lowell is approved for Veterans Administration benefits. Eligible veterans should obtain the necessary application from the Veterans Administration and present it to the Graduate School Office at or before registration. Veterans Administration regulations state that a Veteran must be working toward an advanced degree in order to be eligible for benefits. A Veteran cannot be certified for individual courses.

All recipients of Veterans' benefits are required to certify attendence each month by signing a list available in the Graduate School Office. Failure to do so will be reported to the Veteran's Administration at the end of the month.

UNIVERSITY FEES*

Academic 1985-1986

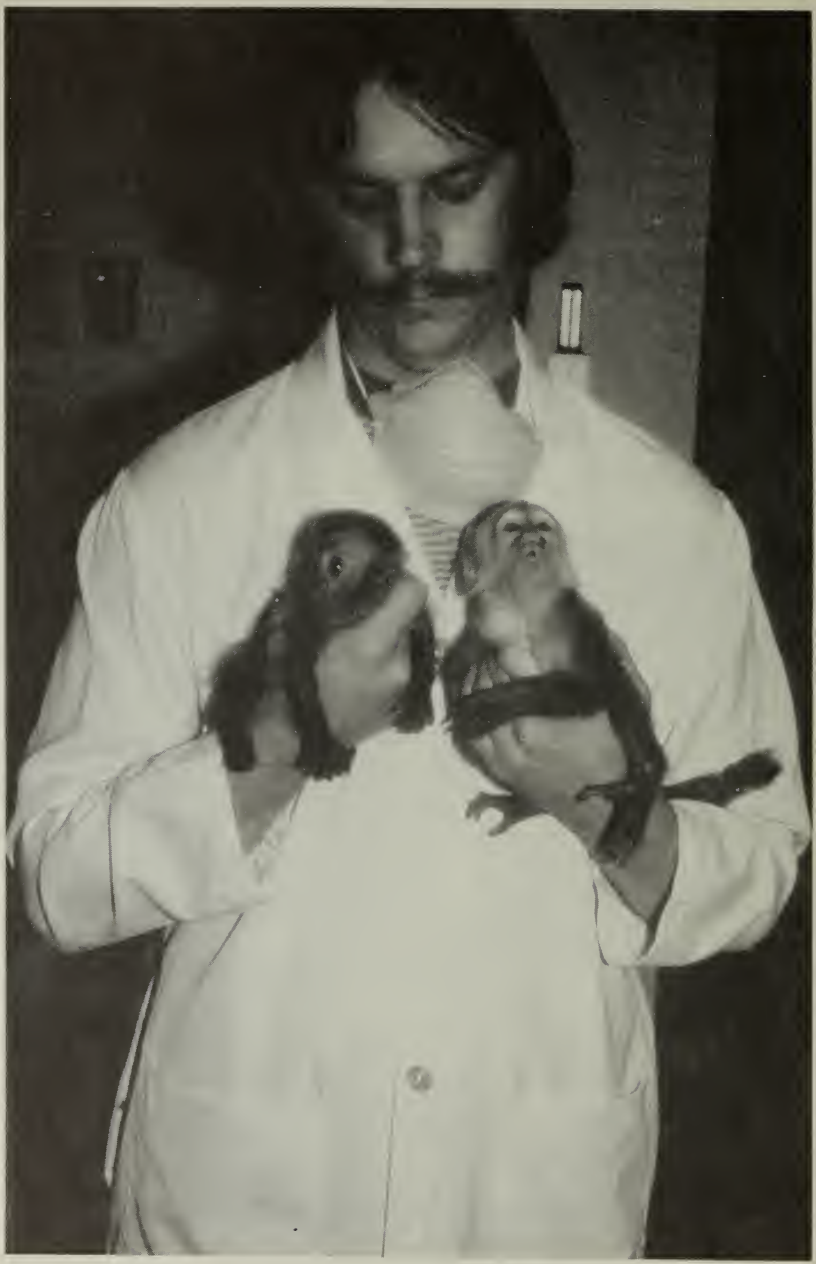
Graduate School	
Tuition (credit hour)	$ 52.50 (in-state)
	$ 155.50 (out-of-state)
Up to a maximum of (per semester)	$ 630.00 (in-state)
	$1,866.00 (out-of-state)
Clinical Supervision	$ 12.00
Continued Advisement	$ 50.00
Late Registration Fee	$ 20.00
Change of Registration Fee	$ 5.25 per transaction
Registration Fee	$ 5.25
Student Union Fee	$ 25.00 maximum
	$ 2.00 per credit hour
Student Activity Fee	$ 15.00
Academic Services Fee	$ 3.00/Academic cr. hr./
Semester maximum	$ 36.50
Engineering/Science Capital Equip. Fee	$ 4.40/Academic cr. hr./
Semester maximum	$ 52.50
Health Professions Fee	$ 2.20/Academic cr. hr./
Semester maximum	$ 26.25
Recreational Services Fee	$ .62/Academic cr. hr./
Semester maximum	$ 7.50
Commencement Fee	$ 30.00
Dormitory Charges	$1,551/calendar year
Married Student Housing	$398/month (2-bedroom)
	$348/month (1-bedroom)
Laboratory Fee	$ 26.25 per lab
Transcript Fee	$ 1.00
International Student Processing Fee	
(charged only once)	$ 26.25
Continuing Education Fees	
Registration Fee	$ 10.50
Tuition (credit hour)	$ 64.00
Late Registration Fee	$ 10.00
Commencement Fee	$ 30.00
Laboratory Fee (where applicable)	$ 26.25
Continued Advisement	$ 50.00

The fees and tuition charges are effective for September 1985 and are subject to change without notice by the Board of Trustees.

Full-time refers to students registered for 9 or more credits.

Part-time refers to students registered for fewer than 9 credits per semester.

The division of Continuing Education reserves the right to establish fees for special conferences, workshops, non-credit offerings, and the like.



ADMISSIONS

Admission Requirements: Admission requirements for graduate study in the University are as follows: (1) a baccalaureate degree or its equivalent from an accredited college or university; (2) a satisfactory scholastic average to demonstrate that the applicant has had adequate preparation for the field in which graduate studies are to be undertaken; (3) a satisfactory score on any appropriate entrance examination required for admission by the program or department to which admission is sought. **Unless otherwise stated in this catalog, the required examination is the GRE Aptitude,** and; (4) additional requirements as may be established by individual programs such as personal interviews or auditions. Refer to individual departmental sections for more specific information.

Departmental Requirements: The rules, regulations, and policies delineated by the Graduate School constitute only the minimum requirements for admission, retention, and graduation. Each department may have additional requirements mandated by the unique nature of the various programs. It is the responsibility of the graduate student to be aware of the minimum requirements of the Graduate School and, in addition, to fulfill the special requirements of the particular program in which s/he is enrolled.

Application Procedure: Application forms and materials may be obtained from the University of Lowell, Graduate School Office, Lowell, Massachusetts 01854. A non-refundable application fee of $10 for Massachusetts residents ($40 for non-residents) must accompany the application. Each applicant must file the following documents: (1) a completed application form, (2) official transcripts of all undergraduate and graduate records sent directly to the Graduate School by the institutions which the applicant attended, (3) three letters of recommendation sent directly to the Graduate School by persons qualified to judge the ability of the applicant to carry on graduate work and research, (4) scholastic test scores specified for various degree programs at the University (see individual departmental requirements), and (5) the "Test of English as a Foreign Language" (TOEFL) for students from countries where English is not the national language. If the TOEFL bulletin cannot be obtained locally, students should write well in advance to: Test of English as a Foreign Language, Box 899, Princeton, NJ 08540, U.S.A. All test scores must be offical and sent directly by the testing agency.

Application Deadline: Completed applications, including all required documents, should be received on or before April 1 for candidates who seek admission for the subsequent summer or fall semester, and on or before November 1 for candidates for the subsequent spring semester.

Types of Admission: Students may be admitted to graduate study at the University of Lowell under the following classifications:

1. **Matriculated status:** Students who have met all requirements for

admission to a degree program and who have been recommended by the department in which they propose to study as a degree candidate.

2. **Provisional status:** Students who have not fully met the requirements stipulated by the program or Graduate School may be admitted as prospective candidates for a degree on a provisional basis. Such students must have as their initial objective the satisfactory completion of all requirements for matriculation. In order to change status from provisional to matriculated, a student must file, with supporting documentation, the appropriate Academic Petition form obtainable in the Graduate School Office.

3. **Non-Degree status:** Students without advanced degree objectives may be admitted to take courses on the basis of non-degree status. Students who wish to take courses as non-degree students must submit a transcript showing the conferral of a bachelor's degree. Such students are not eligible to receive credit toward a degree unless they file a formal application and are then admitted as matriculated students. Upon admission to matriculated status, these students must file an Academic Petition form to have any credits earned previously considered toward an advanced degree; no more than 12 credits earned as a non-degree student at the University of Lowell may be transferred to a degree program, and they must have been completed within five years prior to the date of admission.

Course Credits: All graduate courses for which a student registers are listed on his/her transcript and used to calculate the student's grade point average, whether they are taken to fulfill degree requirements or not.

Transfer Credit: Courses completed elsewhere within five years prior to the date of admission to a graduate degree program at the University of Lowell may be considered for transfer in accordance with the following regulations:

1. A maximum of 10 graduate credits earned with a grade of B or better may be transferred to a master's degree (see individual programs for specific numbers of credits transferrable) and up to 22 credits for a doctoral degree with the appropriate approval.
2. An official transcript and description of the course(s) must be submitted with the written request.
3. The courses presented must be from an accredited institution authorized to grant gradute degrees.
4. The courses presented must not have been used in earning another degree; however, master's degree credits may decrease doctoral or C.A.G.S. minimum credit requirements.
5. The courses presented must be appropriate to the degree program for which the applicant is applying.
6. Transfer credit may not be granted for research seminars, clinical courses, practica, internships, or special projects.
7. Students who wish to transfer credit must file (within the first semester of matriculation) the Academic Petition form obtainable in the Graduate School Office.

Graduate Advising

An entering graduate student is assigned an advisor as soon as possible after arrival on campus. This advisor is selected by the Graduate Committee of the department in which the student is enrolled; s/he will provide advice and academic counseling relative to the student's degree program, including the following:

1. Help design and then approve the student's complete program leading to an advanced degree.
2. Recommend to the coordinator of the program course credits from within and without the University for transfer into the student's degree program.
3. Approve the procedure by which the student intends to satisfy the language requirement (if any).
4. Arrange for the qualifying examination for the student who is applying for admission to a doctoral program.
5. Meet regularly with the student to determine his/her progress toward the degree objective and to help solve any problems that may arise.
6. Report on the student's progress to the coordinator of the program.

Thesis and Dissertation Committees

As soon as a student has chosen an area of research or a project, a Thesis Committee for the master's degree candidate or a Dissertation Committee for the doctoral candidate is selected by the Graduate Committee of the appropriate department, subject to the approval of the Dean of the Graduate School. The number and nature of the committee members depend on the scope of the thesis, project or dissertation, but one member of each committee will be the student's major advisor (in many cases, the student's original advisor). The Dissertation Committee shall consist of at least three members, two of whom shall be from the student's major department. The responsibilities of the Thesis and Dissertation Committees shall be to:

1. Approve the research topic.
2. Supervise the progress of the thesis or dissertation (major advisor only).
3. Arrange for the oral defense of the thesis or dissertation.
4. Report the fulfillment of all thesis, project, and dissertation requirements to the Departmental Graduate Committee.

ACADEMIC EXPENSES AND FINANCIAL ASSISTANCE

New England Regional Student Program. The University participates in this reciprocal program in which qualified and legal residents of New England may attend the Graduate School and pay in-state tuition charges, plus 25%. Applicants are considered for unique and distinctive graduate level studies not available at their home state university. Full details are

available from the New England Board of Higher Education, 45 Temple Place, Boston, Massachusetts 02111 or at the University of Lowell Graduate School Office.

Refund Policy.
Full-time students (registered for 9 or more credits) are eligible for tuition refunds (no fees are refundable) only if they withdraw from the University in good standing. *Such students must fill out the withdrawal form obtainable in the Graduate School Office.* A student who makes an advance payment and then for any reason does not attend any part of the next semester, *and who so notifies the Graduate Office within the first ten days of a semester,* will be given a full refund of tuition and fees. Tuition refunds are granted in accordance with the following schedule (No fees are refundable.):

Before the beginning of the second week	80% refund
From the second week but before the third week	60% refund
From the third week but before the fourth week	40% refund
From the fourth week but before the fifth week	20% refund
From the fifth week on	No refund

Part-time students (registered for fewer than 9 credits) are eligible for tuition refunds according to the following schedule, if they withdraw officially from one or more courses:

Before the first class	100% refund
After the first week but before the second week	80% refund
After the second week but before the third week	60% refund
After the third week	No refund

Students enrolled under Continuing Education programs are eligible for tuition refunds according to the following schedule, if they withdraw officially from one or more courses:

Tuition refunds are based on the academic calendar not class attendance - and are pro-rated as follows:

Withdrawal before the first meeting	100% refund
After the first but before the second	90% refund
After the second but before the third	50% refund
After the third	No refund

(Fees are not refundable unless Continuing Education is responsible for cancellations).

Students desiring refunds must file an application form obtainable at the Continuing Education Office. Allow 4-6 weeks from the time the request is submitted.

Insurance. Graduate students are required to purchase accident insurance. The present rate is about $15 per academic year. Additional medical insurance is also available on an optional basis. Waiver of the accident insurance is possible with proof of self-insurance. International students *must* subscribe to full medical insurance; the present cost is about $200 per academic year.

Thesis. Every graduate student who completes a thesis is required to bear the cost of microfilming and binding at least three copies of the thesis for the University's files in accordance with the following schedule:

Binding fee (per copy)	$ 8.00
Microfilm fee (master's)	$20.00
Microfilm fee (doctorate)	$30.00
Copyright fee (M.S., Ph.D.)	$20.00

Graduate students who have registered for the number of thesis credits required for the degree but who have not yet completed their thesis research must register for Research Participation and pay a tuition charge for a minimum of three credits. Graduate students who have completed all the requirements except the writing and defense of a thesis and do not need to carry out any further laboratory work must register for 00.601 Continued Advisement and pay a registration fee each semester.

Financial Aid. Financial need will be determined after the student has filed the FAF (Financial Aid Form) or GAPSFAS (Graduate and Professional School Financial Aid Service) available in the Financial Aid Office, with the College Scholarship Service, Princeton, New Jersey. The major source of financial aid recommended to students is the Guaranteed Student Loan Program (also known as HELP loans). These loans are obtained through local banks, and the student may borrow up to $5,000 at a low interest rate per year for graduate work. Information regarding interest rates, repayment schedule, and eligibility for these loans may be obtained from the Financial Aid Office or your participating lending institution.

The college-based financial aid available at the University of Lowell is the National Direct Student Loan, and the College Work Study Program. To be considered for these programs, students must complete and return the University of Lowell Financial Aid Forms to the Director of Financial Aid at the University. For more information, students should call or write the Director of Financial Aid.

ASSISTANTSHIPS AND FELLOWSHIPS

Assistantships. A limited number of teaching assistantships are available for qualified students. These are administered by the Graduate School and the student's department. A student who is to receive an assistantship will be notified and sent a contract by the department. Stipends vary, and the contract will be for the academic year. Reappointments in succeeding years are contingent upon satisfactory performance of duties as well as academic achievement. Tuition is waived for all full-time graduate assistantships.

Fellowships. Fellowships generally are available only for advanced graduate students and through special arrangement with individual research advisors. Full-time fellowships may include tuition waivers. These

waivers must be obtained with a special form and must be renewed before September every year.

Graduate Student Assistantships. A limited number of student assistantships are available in the departments. Students in this category are given specific assignments, such as administering laboratory quizzes or grading under the supervision of a faculty member. Students in this category are paid a specified sum per hour of work. No waiver of tuition is available for this category of assistantship.

Summer Research Fellowships. Summer Research Fellowships generally are available from the Research Council. These grants are used to help support graduate students carrying out their thesis research during the summer months. In order to qualify for this support, students write a research proposal which must be approved by a screening committee of the Research Council. The amount of this support varies, depending upon the funds available.

All queries concerning assistantships and fellowships should be directed to the graduate program coordinator in the student's department.

Continuous Registration of Graduate Students. Matriculated students must register each fall and spring until their program of studies is complete and the degree has been earned. Graduate students who plan to receive an advanced degree in October, however, must register for the previous Summer Session in order to maintain continuous matriculation. If for any reason a student is not registered for a course (because of leave of absence or because all course work except the thesis is complete) s/he must register for 00.601 (Continued Advisement) in order to maintain continuous matriculation. Master's degree candidates may register for 00.601 for not more than one academic year, doctoral candidates for not more than three academic years. A student who fails to maintain continuous matriculation loses his/her status as a degree candidate and must reapply to the Graduate School for readmission and for renewal of candidacy.

Degree requirements for the master's degree must be completed within a five-year period, and for the doctoral degree within an eight-year period from admission as a matriculated student.

International students may not sign up for Continued Advisement and must register as full-time day students each semester.

Course Numbering System

400-499	Undergraduate courses taken for graduate credit with permission of advisor
500-599	Graduate credit
600-up	Graduate credit; graduate students only.

Academic Grades. The grading system uses grades A, AB, B, BC, C and F with the numerical equivalents of 4.0, 3.5, 3.0, 2.5, 2.0 and 0. The following special grades are also used: I (Incomplete), S (Satisfactory, B or better), U (Unsatisfactory), AU (Audit), W (Withdrawal from a course or from the University), X (Withdrawal because of illness or personal emergency), Y (Administrative dismissal), Q (Never attended but did not withdraw), and PR (In Progress for courses in Research and Thesis). Candidates registering for research will do so in 3-credit multiples each semester up to a total number recommended, and students registering for seminar will register for 1-credit multiples each semester. No graduate degree will be awarded to a student whose cumulative average for course work is below 3.0. The cumulative average is computed from all graduate level courses taken at the University of Lowell, unless a specific request is received from the student's departmental graduate committee to omit specific courses from the average.

Incomplete. If, because of circumstances beyond a student's control, s/he is unable to meet all the requirements of the course by the end of that semester, the grade of I (Incomplete) may be given. The award of this grade requires an understanding between the instructor and the student concerning the completion of course work. The maximum time limit for submission of all course work necessary for removal of an Incomplete is the last day of

classes of the next semester following the semester (or Summer Session) in which the grade was received. After that time, an unchanged grade of Incomplete is changed automatically to F. An extension of the time limit is possible but must be approved, prior to the expiration date stated above, by the instructor and the Dean of the College through which the course is offered. Written approval indicating the new time limt must be filed with the Dean of the Graduate School.

Audit. A graduate student may, upon approval of the advisor and the instructor, register for a course on an audit basis. Audit students are not required to take tests or the final examination. A change in registration from audit to credit or vice versa must be effected during the add/drop period. Under no circumstances can a course be taken for audit be given credit at a later date.

Withdrawal. Students finding it necessary to withdraw from a course must do so with departmental approval in the time specified in the academic calendar. The student's permanent record will indicate a grade of W for the course(s) from which s/he has withdrawn unless the withdrawal has taken place in the first 10 days of the semester, during which time no record will be kept.

Students who wish to withdraw from the University must obtain a withdrawal clearance form from the Graduate School and have it completed in triplicate. This procedure ensures that the student's academic and financial obligations are cleared before s/he leaves the University. For students officially withdrawing from the University, the permanent record will indicate a grade of W, if approved by the individual instructors of courses pursued at the time of withdrawal. If the student fails to follow the official withdrawal procedure and does not withdraw in good standing, official transcripts of the student's academic record will not be issued and the student will not be permitted readmission to the Graduate School except under extenuating circumstances. A student's file will remain active up to two years after withdrawal. At any time during this period, students may request readmission by writing to the Graduate School. After two years, students must file a new application in order to be readmitted to the Graduate School.

In Progress. For courses in Research and Thesis, the student is assigned the grade PR (In Progress). This grade will be indicated on the student's record each semester until the research or thesis is completed. During the semester when the work is completed, the grade of S or U will be given.

Graduate Credit for Undergraduate Courses. Courses at the 400 level are designed for seniors but under certain circumstances may be taken by graduate students for graduate credit. The student is required to file a Special Petition form obtainable in the Graduate School, at the time of registration. If a graduate student takes certain undergraduate courses to make up background deficiencies, the course credit hours are not used as

part of the graduate degree program. A maximum of 6 credits of 400 level courses may be used for graduate credit toward the degree.

Undergraduate Credit for Graduate Courses. Qualified juniors or seniors who wish to take any courses at the 500 level for undergraduate credit must obtain the necessary approval by means of a Special Petition form. The grade received in any such course is used in calculating the undergraduate's cumulative grade point index. Such students may not earn graduate credit until they have completed all requirements for the bachelor's degree.

Non-Degree Credit. Non-degree students who apply for matriculated status as degree candidates may transfer no more than 12 credits earned in the non-degree classification. Departments may further limit the number of transferrable credits.

Changes in Registration. Courses may be added, dropped, or changed from audit to credit by completing the appropriate add/drop forms and obtaining the permission of the student's advisor. This may be done during the first 10 academic days of the semester. Courses dropped will not appear on the student's permanent record. After this period, no new courses may be added and no course may be changed from audit to credit or vice versa. Students wishing to drop courses may do so by the date indicated on the Graduate School Academic Calendar, and these courses will appear as W on the student's record. *All changes in registration must be brought to the Graduate School Office for processing or they will not appear on the student's record.*

Change of Major. In order for a student to change major or area of concentration, s/he must have an Academic Petition signed by the coordinator and department chairperson of the new and old major. This petition should include the acceptance of the student to the new program, and should indicate the courses and the total number of credits that may be transferred to the student's new degree program. A new application fee will be charged for this transaction.

Transcripts. In order to obtain a transcript, a student must submit his/her name, major and year attended or graduated to the Registrar's Office through a written request by mail or by filling out the appropriate forms available in the Registrar's Office. Transcripts given directly to students do not carry the University seal and are not official. The seal is attached when the transcript is mailed directly from the University to the receiving party.

Retention Policy. No more than 6 credits of C and/or BC may be counted towards the master's degree; no more than 9 credits of the same grades may be counted toward the doctorate. No advanced degree will be awarded any student whose overall cumulative average falls below 3.0. Students earning one C or BC will be reviewed by their advisor and the coordinator of the appropriate program. Students earning two C's or BC's will be reviewed by

the Graduate Committee of the appropriate department for such action as a warning, probation, loss of degree candidacy, etc. Those receiving more than two C's and/or BC's or any grade lower than a C will be reviewed by the Graduate Committee of the appropriate department for such action as dismissal, probation, loss of degree candidacy, imposition of additional requirements, etc. Action on such students is subject to the approval of the dean of the appropriate college. The Dean of the Graduate School may at any time examine the performance of any student not living up to the academic standard expected of graduate students and recommend to the appropriate graduate committee a course of action to remedy the situation. Graduate students dropped for academic reasons may appeal to the graduate committee of the appropriate department or College for review of the decision. Such students dissatisfied with the appeal decision at this level may appeal ultimately to the Dean of the Graduate School.

REQUIREMENTS FOR DEGREE CONFERRAL

General Requirements for the Master's Degree

To be recommended for a master's degree, a candidate must satisfy requirements of the Graduate School and the specific requirements of the college in which s/he is enrolled. The requirements of the Graduate School are given below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master's degree must:

1. Complete a course of study designed by the department in which s/he is enrolled and approved by the Graduate School. The approved course of study must have a minimum of 30 credit hours of graduate study including, where applicable, a thesis or project in the student's chosen field.

2. Where applicable, complete a master's thesis or a master's project which will consist of scholarly investigation, such as a review, report, synthesis or design in the student's field. The thesis or project must be of the quality expected of graduate study and be approved by the department in which the student is enrolled and by the Graduate School. A thesis reporting the results of research must conform to the format specified in the Thesis Guide, which is available in the Graduate School Office. The only grades given for thesis work are S (Satisfactory), U (Unsatisfactory), and PR (In Progress). Three copies of the thesis abstract and abstract title page must be filed in the Graduate School Office.

3. Successfully pass any oral or written examination on his/her complete master's program that the department may require.

4. Earn satisfactory grades in all subjects offered for the degree. The lowest grade acceptable for graduate credit is C, but the overall cumulative average of all courses taken must be at least 3.0. All undergraduate subjects taken to clear deficiencies in the student's preparation for graduate work, but which are taken during his/her enrollment as a graduate student must be passed with a grade of at least C. However, these courses may not be submitted as part of the course of study leading to the master's degree.

5. Fulfill departmental language requirements where applicable.

6. Satisfy all requirements as to tuition, fees and expenses as evidenced by completing and submitting the Advanced Degree Clearance form to the Graduate School Office. At this time the student will be asked to make an appointment for an exit interview at the Graduate School.

Combined B.S./M.S. Degree Programs

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, several departments have instituted a program of accelerated study which leads to a master's degree. Presently, these programs are offered in the following departments: Chemical Engineering, Civil Engineering, Environmental Studies, Electrical Engineering, Energy Engineering, Mechanical Engineering, Paper Engineering, Plastics Engineering, Biological Sciences, Radiological Sciences and Mathematics.

To be eligible to enter this course of study, the student must file a formal Graduate School application in the junior year, but need not take the Graduate Record Examination. Upon recommendation of the student's advisor, and with the approval of the departmental graduate admissions committee and the Dean of the Graduate School, the student may be admitted to graduate study during the senior year. Upon the recommendation of the graduate admissions committee of the department and the approval of the Graduate School Dean, the student officially becomes a provisional graduate student in the second semester of the senior year.

The student will then receive a bachelor's degree at the end of the fourth year of study, if all course requirements have been met. S/he may then be recommended for status as a fully-matriculated student upon recommendation of the departmental admissions committee and approval of the Dean of the Graduate School before the start of the fifth year.

Graduate or advanced undergraduate (400 level) courses taken during the senior year may be used for both the graduate and undergraduate degrees up to the amount indicated by each of the individual programs. The total number of credits used for the combined degree must, however, be greater than the minimum number of credits required to obtain an undergraduate degree. As an example, if the student's department requires 132 credits, and the University B.S. requirement is 120 credits, the student may, with approval, transfer up to 12 credits toward the master's degree.

As in the regular M.S. program, the department may or may not require a thesis or additional courses, as specified by the rules and regulations. The student must also meet all departmental and Graduate School regulations for the M.S. degree.

Students taking full advantage of the combined program ordinarily would be expected to finish the M.S. degree at the end of the fifth year of study. However, this will depend upon the student's course load and thesis work. The student may be eligible for financial assistance, i.e., fellowships and teaching assistantships, during the fifth year of study, but this may delay completion of the program. See individual programs in this catalog or consult departmental coordinator for further information.

Requirements for Doctorates

The degree is conferred upon graduates who have met the following requirements:

1. The successful completion of graduate courses in the major fields. The student's Dissertation Committee and advisor will determine the number of graduate credits which the student must earn, but a program consisting of between 70 and 80 credits, including 24 in research, is considered average.

2. The satisfactory completion of the language requirements specified by the major department.

3. The passing of a comprehensive qualifying examination, oral and written, to be conducted by the major department and to be passed not later than eight months before the completion of the candidate's work. If the student fails the comprehensive examination s/he may, at the discretion of the Dissertation Committee or advisor, be permitted a second and final opportunity.

4. The holding of a Teaching Assitantship for a minimum of two semesters. (This requirement may be waived.)

5. The preparation of a dissertation based upon the results of original research which is satisfactory to the Dissertation Comittee and the major department.

6. The passing of a final oral examination conducted by the Dissertation Committee, primarily upon, but not necessarily limited to, the contents of the candidate's dissertation. The examination cannot be scheduled until all members of the Dissertation Committee and the major department have approved the dissertation. The oral examination is to be conducted by the Disseration Committee, whose membership may be augmented by the non-voting faculty and representatives of the Graduate School. In order to pass, the candidate may not receive more than one dissenting vote from the members of the Dissertation Committee.

7. The satisfactory completion of the residence requirement. The equivalent of at least one academic year of full-time graduate work must be spent at the University. The requirement for a year in residence may be satisfied only by the student's physical presence on campus for two consecutive semesters. This may be either a fall-spring sequence, or a spring-fall sequence. It cannot be satisfied by a summer session and a semester of the regular school year.

8. The completion of all doctoral requirements within eight years after the student's admission as a matriculated graduate student. Extension beyond this time may be granted only with the joint approval of the student's Advisory Committee, Department Chairperson, College Dean, and Dean of the Graduate School.

9. The satisfactory completion of all financial obligations (tuition, fees, and expenses) as evidence by completing and submitting the Advanced Degree Clearance form to the Graduate School Office. At this time, the student will be asked to make an appointment for an exit interview at the Graduate School.

10. Full-time faculty of the University of Lowell are not eligible to earn a doctorate at this University.

Graduate Foreign Language Policy

The Graduate School specifies that individual departments establish departmental language requirements for both master's and doctoral degree candidates according to the levels of competence and overall policy given below. The department will decide the number of foreign or computer languages and the level of competency it wishes to require in each. For purposed of these requirements, a foreign language will be defined as a language other than the student's native tongue and one in which there is a significant body of literature relevant to his/her academic discipline.

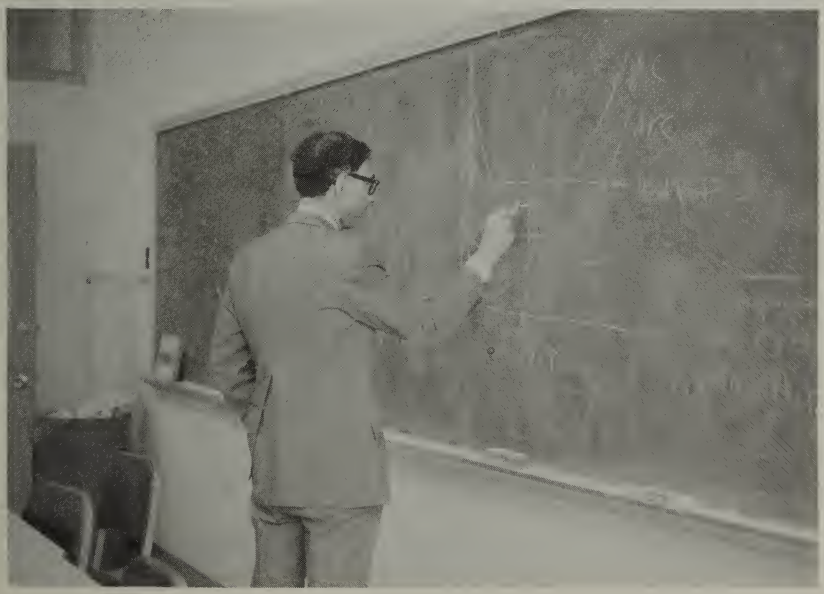
The alternative levels of competency which a department may select are:

1. Reading Level: Equivalent to the knowledge required in two to four years of undergraduate study.

2. Journal Level: Knowledge sufficient to understand journals in the language in the student's academic discipline with the aid of a dictionary.

3. Foreign language competency: A department may select any of these levels or any combination of them for as many languages as it wishes. When a department selects level one, the student's competence will be decided by the Graduate School Foreign Language Test, which is prepared and scored by the Educational Testing Service, Princeton, New Jersey. The passing grade for this level will be specified by the Graduate School Executive Committee. When a department selects level two, the students competency will be decided by a departmental committee, with the advice and cooperation of the Department of Languages.

A master's degree candidate will be expected to satisfy departmental language requirements before formally submitting his/her thesis or project proposal, and a doctoral student will be expected to satisfy departmental language requirements prior to being admitted to candidacy.



GRADUATE EXECUTIVE COMMITTEE MEMBERS

Jerome Hojnacki.....Biological Sciences, Chairman
Alfred Donatelli.....Chemical Engineering, Vice Chairman
Edward Alexander .....Radiological Sciences
Albert Altman.....Physics
Donald Ameen.....Mathematics
Eugene Barry .....Chemistry
Norman Benson.....Education
Elizabeth Daly.....Nursing
Nathan Gartner .....Civil Engineering
Steven Grossman .....Plastics Enginering
Anne McParland.....Education
William Moeller .....Environmental Studies
Charles Nikitopoulos .....Psychology
James Powers .....Electrical Engineering
Ralph Rieth.....Management
Struan Robertson .....Mechanical Engineering
James Sheff.....Energy Engineering
Willis Traphagan .....Music

Linda Silka, Psychology, ex officio
Harry Rubinstein, Dean of the Graduate School, ex officio
Paula I. Robbins, Assistant Dean of the Graduate School, ex officio

GRADUATE FACULTY

This listing includes all members elected to the Graduate Faculty at the University of Lowell as of September 1, 1983.

Douglas Adamson, *Assistant Professor, Education;* A.B. Yale University; M. Div., Episcopal Divinity School; J.D., Ed.D., Harvard University

Frank Alberti, *Associate Professor, Industrial Technology;* B.S.C.E., Tufts University; M.S.C.E., Worcester Polytechnic Institute; M.S.M.E., Northeastern University; Ph.D., University of New Hampshire

Edward Alexander, *Professor, Physics;* B.S., M.S., University of Maine; Ph.D., Vanderbilt University

Jack D. Alexander, *Associate Professor, Management;* Ph.D., University of Notre Dame

Albert Altman, *Professor, Physics;* Ph.D., University of Maryland

Donald L. Ameen, *Associate Professor, Mathematics;* M.S., Cornell University

Martin Ames, *Lecturer, Health Services;* B.S., Cornell University; M.B.A., New York University; M.A., University of California at Berkeley; J.D., Suffolk University Law School

Ruth Ashley, *Assistant Professor, Music;* B.M., M.Ed., Lowell State College; M.Ed., Fitchburg State College

Susan Assmann, *Assistant Professor, Mathematics;* B.A., Dartmouth College; Ph.D., Massachusetts Institute of Technology

Mario Aste, *Professor, Language;* Ph.D., Catholic University

Francesco L. Bacchialoni, *Associate Professor, Electrical Engineering;* Dott. Ing., University of Genova (Italy)

Adolph Baker, *Professor, Physics;* Ph.D., Brandeis University

William W. Bannister, *Professor, Chemistry;* Ph.D., Purdue University

Eugene F. Barry, *Associate Professor, Chemistry,* B.S., Villanova University; Ph.D., University of Rhode Island

Patricia Bartels, *Instructor, Nursing;* B.S., University of California, Los Angeles; M.S., University of California, Davis

Roger Baumann, *Professor, Electrical Engineering;* Sc.D., University of Paris

Norman F. Benson, *Associate Professor, Education;* B.S., A.M., University of Minnesota; Ed.D., Ball State University

Shimshon Berkovits, *Associate Professor, Mathematics;* Ph.D., Northeastern University

M. Virginia Biggy, *Professor, Education;* B.S., Ed.M., Ed.D., Boston University

Alexandre Blumstein, *Professor, Chemistry;* Ph.D., University of Strasbourg

Rita Blumstein, *Professor, Chemistry;* Ph.D., University of Delaware

Norman Bolyea, *Assistant Professor, Civil Engineering;* B.S., Worcester Polytechnic Institute; M.S., Ph.D., Rensselaer Polytechnic Institute; P.E.

Dean D. Bouzianis, *Assistant Professor, Music;* B.M., A.M., Boston University; M.M., National Conservatory of Greece

N. Bradford Brakke, *Adjunct Professor, Plastics Engineering,* B.S., North Dakota State University; M.S., Butler University

Donald Bravo, *Professor, Music;* B.M., New England Conservatory; M.M., Boston University

John Brode, *Assistant Professor, Mathematics;* M.S., Ph.D., Harvard University

Carol Brown, *Associate Professor, Sociology;* Ph.D., Columbia University

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Robert White, *Music;* B.M., New England Conservatory; A.M. Harvard University
Joyce W. Williams, *Assistant Professor, Mathematics;* Ph.D., University of Illinois
Martin Wilner, *Professor, Physics;* Ph.D., Massachusetts Institute of Technology
Chuen Wong, *Assistant Professor, Physics;* Ph.D., Case Institute of Technology
Lee-Jun Wong, *Assistant Professor, Biology;* B.S., National Taiwan University; Ph.D., Ohio State University
Shan S. Wong, *Associate Professor, Biochemistry;* Ph.D., Ohio State University
David Wunsch, *Associate Professor, Electrical Engineering;* B.E.E., Cornell University; S.M., Ph.D., Harvard University
Louis E. Yelle, *Associate Professor, Management;* B.S., Lowell Technological Institute; M.S., M.B.A., Northeastern University
Woon-Shing Yeung, *Assistant Professor, Mechanical Engineering;* B.S., University of Lowell; M.S., Ph.D., University of California
Yakov Ziberberg, *Associate Professor, Mechanical Engineering;* M.S., Technical Institute, Odessa, U.S.S.R.; Ph.D., University of New Hampshire

COLLEGE OF EDUCATION

DEAN: M. VIRGINIA BIGGY, *Professor;* B.S., Ed.M., Ed.D., Boston University.

CHAIRPERSON OF THE FACULTY: DOROTHY V. MEYER, *Associate Professor;* A.B., Houghton College; Ed.M., Ed.D., Boston University.

GRADUATE COORDINATORS: ANNE M. McPARLAND, *Associate Professor;* B.S., University of Lowell; C.A.S., Harvard University; Ed.M., Ed.D., Boston University, and **GAIL M. CARNEY,** *Assistant Professor;* B.A., Framingham State College; Ed.M., University of Lowell; Ed.D., Boston University.

DISTINGUISHED VISITING PROFESSOR: OLIVE S. NILES, *Professor, Reading and Language Education;* A.B., Mount Holyoke College; A.M., Bryn Mawr College; Ed.D., Boston University.

FACULTY:

Douglas H. Adamson, *Assistant Professor;* A.B., Yale University; M. Div., Episcopal Divinity School; J.D., Ed.D., Harvard University.
Norman F. Benson, *Associate Professor;* B.S., A.M., University of Minnesota; Ed.D., Ball State University.
John J. Catallozzi, *Associate Professor;* B.S., University of Lowell; Ed.M., Ed.D., Boston University.
Thomas G. Devine, *Professor;* B.S., M.A., Ed.D., Boston University.
Brenda L. Jochums, *Associate Professor;* B.S., University of Illinois; M.A., Bradley University; Ph.D., Indiana University.
Richard G. Lyons, *Professor;* B.S., Ed.M., Ph.D., Boston University.
William T. Phelan, *Associate Professor;* A.B., Boston College; A.M., Catholic University; Ph.D., University of Chicago.
Donald E. Pierson, *Professor;* A.B., Princeton University; Ed.M., Ph.D., Harvard University.
Carolynn A. Washbon, *Assistant Professor;* A.B., George Washington University; M.A., Ph.D., University of Maryland.
Penelope A. Demogenes, *Associate Professor Emerita;* B.S., University of Lowell; Ed.M., C.A.G.S., Boston University.
Alice C. Kiernan, *Associate Professor Emerita;* B.S., University of Lowell; Ed.M., Boston University.
Margaret R. Shannon, *Dean Emerita and Professor;* B.S., University of Lowell; Ed.M., Ed.D., Harvard University.

The College of Education offers graduate degree programs which provide professional preparation for those who aspire to serve in the role of teacher, educational specialist, educational or human service manager and media and educational computer specialist. The Master of Education degree is offered in:

Curriculum and Instruction (with options in Computer Education, Economics Education, Experienced Teachers, Initial Certification, Technology & Learning Environments)
Educational Administration (with an option in Human Services (non-Health Services Related))
Reading and Language

The Certificate of Advanced Graduate Study is offered in Reading and Language.

The College of Education is organized according to centers of interest for teaching and research. They are: the Center for Reading and Language; the Center for Administration, Planning and Policy; and the Center for Curriculum and Instruction. The Faculty of the Centers are responsible for the degree programs appropriate to their areas of expertise. In addition, the Office for Field Services is responsible for all the placement of apprentice teachers, field-based course work and experiences, and community relations.

ADMISSION TO DEGREE PROGRAMS IN EDUCATION

Application Procedure:

Each applicant must file the following documents with the Graduate School:

1. A completed application form obtained from the Graduate School office.
2. One copy of his/her teaching certificate must be mailed with the completed application form, if applicable.
3. Two official transcripts from each undergraduate college and graduate school which the applicant attended. These official transcripts must be sent to the Graduate School by the Colleges which the applicant attended. Transcripts or copies thereof sent by the applicant are not official and will not be accepted.
4. When applying for any Ed.M. program, an official copy of the applicant's scores obtained on the Miller Analogies Test or G.R.E. must be mailed directly to the Graduate Office by the institution which administered the test.
5. Letters of recommendation from three persons who are qualified to evaluate the applicant's academic and professional abilities. The forms for such recommendations are contained in the admission packet.

Upon receipt of the above documents, the Graduate School will forward them to the College of Education. All decisions on admissions are made by the Graduate Admissions Committee of the College of Education and forwarded to the Graduate School for final action.

ADMISSION STATUS

Applicants may be admitted to graduate study in Education in one of the following categories: Matriculated, Provisional, Non-Degree Status.

Matriculated Status: Applicants who have met all requirements for admission to a degree program in the College of Education and who have been recommended for admission by the Academic Standards and Admissions Committee will be admitted to matriculated status.

Provisional Status: Applicants who have not met all stated requirements for admission to a degree program in the College of Education but

whose record shows promise may be admitted on a provisional basis. Students admitted to provisional status are required to complete nine (9) semester hours of required course work with a cumulative grade point average of no less than 3.25. The records of students on provisional status will be evaluated at the end of each semester, and upon the completion of nine (9) semester hours of required course work, the student will be notified whether he/she qualifies for matriculated status or for termination of his/her enrollment in a degree program. If the student is eligible for matriculated status, the appropriate Academic Petition form must be filed by the student.

Non-Degree Student: All students who register for graduate courses in this University without filing a formal application for admission to a degree program in Education are presumed to be taking graduate courses for reasons other than earning a degree at this University and are classified as Non-Degree Students. They must present an official copy of their undergraduate transcript indicating receipt of a bachelor's degree to the Graduate School Office in order to receive credit and final grades.

In the event that such a student applies for admission to a degree program in the College of Education, no more than nine (9) semester hours credit earned with a grade of B or better while enrolled as a non-degree student may be transferred to the degree program. Transfer of such credits must be in accordance with the regulations governing transfer credits in the College of Education and the Graduate School.

REQUIREMENTS FOR ADMISSION

To qualify for admission to a graduate degree program at the *Master of Education* level, an applicant must have:

1. Earned a baccalaureate degree from an accredited college or university;
2. Completed his/her baccalaureate degree program with a scholastic record that gives evidence of ability to do graduate work with a cumulative average of no less than 2.75 (on a 4.0 scale).;
3. Achieved a score not lower than the 60th percentile on the Miller Analogies Test, or a comparable score on the G.R.E.;
4. Where applicable, qualified for and been granted a teaching certificate by a state certification office;
5. Received approval for admission by the Graduate Admissions Committee of the College of Education and the Graduate School.

To qualify for admission to the *Certificate of Advanced Graduate Specialization*, an applicant must have:

1. Earned a master's degree at an accredited college or university;
2. Completed his/her master's degree program with a cumulative grade point average of no less than 3.0;
3. Received approval for admission by the Graduate Admissions Committee of the College of Education and the Graduate School.

Transfer Credit: Ed.M. and C.A.G.S. Programs

Courses completed within five (5) years prior to the date of admission as a matriculated student may be considered for transfer in accordance with the following regulations:

1. No more than six (6) semester hours (Master's) or nine (9) semester hours (C.A.G.S.) of graduate credit earned with grade of B or better may be transferred from other institutions of higher education;

2. A request for transfer of such credit must be made in writing by the applicant and must be filed with his/her application for admission;

3. An official description of the course(s) must be submitted with the written request;

4. The courses presented must be resident courses completed on the campus of an accredited institution authorized to grant the graduate degree which the applicant is currently seeking;

5. The courses presented must not have been used in earning another degree;

6. The courses presented must be appropriate to the degree program for which the applicant is applying;

7. Transfer credit may not be granted for research seminars, clinical courses, practicums, or internships;

8. The transfer of all course credits must be approved by the Graduate School Office and the College of Education.

Graduate Advisor

A student who accepts admission will be assigned to a faculty advisor in the College of Education. The advisor's responsibility is to: 1) provide academic counseling to the student relative to his/her program; 2) approve the program of studies which the student shall present, and also approve all changes in that program; and 3) periodically evaluate the student's academic progress and make recommendations to the Graduate Admissions Committee concerning the student's continuance, dismissal, or recommendation for a degree.

DEGREE REQUIREMENTS

Each graduate student is personally responsible for complying with all the rules and regulations of the Graduate School and the College of Education, and fulfilling all degree requirements.

In order to qualify for a *Master of Education Degree*, each candidate must meet the following requirements:

1. Complete a minimum of thirty semester hours of required course work in a specific degree program. Some degree programs have a higher minimum semester hour credit requirement.

2. Complete all course requirements for the degree program at this University. A maximum of six (6) semester hours of course work taken at another accredited institution is the only exception given.

3. Complete satisfactorily the specified internship and/or field practicum, and appropriate seminar, under the supervision of a designated faculty member in the College of Education. This requirement may not be waived.

4. Complete all course requirements for the degree with a cumulative grade-point average of B or better. No additional course credits may be permitted in order to achieve the grade-point average of B or better required for the degree.

5. Complete the degree within five years of the date of notification of admission.

In order to qualify for a *Certificate of Advanced Graduate Specialization,* each candidate must meet the following requirements:

1. Complete a minimum of 30 semester hours of required course work in the specified certificate program.

2. Complete all course requirements for the certificate program at this University. A maximum of nine (9) semester hours of course work taken at another accredited institution is the only exception granted.

3. Complete all course requirements for the certificate with a cumulative grade-point average of B or better. No additional course credits may be permitted in order to achieve the grade-point average of B or better required for the certificate.

4. Satisfactorily complete a qualifying paper as approved by his/her area faculty committee.

5. Satisfactorily pass an area comprehensive examination.

6. Complete the certificate program within five years of the date of notification of admission.

Master of Education Degree Programs (Ed.M.)

A. Initial Teacher Certification Program: Elementary Education (Ed.M.): This degree program in teacher education is designed for those who plan to teach in the elementary school and to achieve teacher certification in Elementary Education, Grades 1-6. The degree requirements include the following:

I. Completion of these graduate courses at the University of Lowell:

02.565	Developmental Psychology	3 Sem. Hrs.
02.558	Measurement and Evaluation	3
02.550	Reading Education: Elementary	3
02.553	Language Education: Elementary	3
02.556	Reading Disabilities	3
02.555	Literature for Children	3
02.551	Mathematics Education: Elementary	3
02.552	Social Studies and Science Education	3
02.554	Analysis of Teaching	3
02.579	Seminar in Elementary Education	2
02.559	Education's Response to Cultural Diversity	3
02.578	Teaching: Elementary	12
		44 Sem. Hrs.

II. Completion of the Elementary Education Field of Knowledge Certification requirement. These requirements are prerequisites and must have been completed satisfactorily as part of the baccalaureate degree. This list is available from the graduate coordinator on request.

B. Initial Teacher Certification Program: Secondary Education (Ed.M.): This degree program in teacher education is designed for those who plan to teach in the secondary school and to achieve teacher certification in Secondary Education, Grades 9-12. The degree requirements include the following:

I. Completion of these graduate courses at the University of Lowell:

02.565	Developmental Psychology	3 Sem. Hrs.
02.558	Measurement and Evaluation	3
02.564	History of American Education	3
02.560	Curriculum Development: Middle/Secondary	3
02.XXX	Curriculum & Teaching in Major Area	3
02.557	Reading Education: Middle/ Secondary	3
02.596	Seminar in Secondary Education	3
02.559	Education's Response to Cultural Diversity	3
02.XXX	Teaching: Major Area Secondary	3
		36 Sem. Hrs.

II. Completion of the Secondary Education Field of Knowledge Certification requirement. These requirements are prerequisites and must have been completed satisfactorily as part of the baccalaureate degree.

C. Curriculum and Instruction Degree Program (Ed.M.): The program in Curriculum and Instruction is designed for teachers in elementary and secondary schools who will provide instructional leadership in the role of supervisor or department chairperson, and for those who will provide leadership in curriculum development in their role as a curriculum specialist. There are a number of options - Economic Education, Experienced Teacher Option, Computer Education, Technology and Learning Environments, Initial Teacher Certification.

The degree requirements for the Ed.M. include the following:

I. Behavioral and Humanistic Requirements
Area I. 07.640 Research Methods or 07.650 Computer Literacy is required of every student.

At least two other courses selected from Area II - Humanistic Foundations, or Area IV - Sociological Foundations are required.

II. Specialization in Curriculum and Instruction

The following courses are required of all degree candidates:

04.638 Theory and Research in Curriculum
04.639 The Planning Process

04.637 Curriculum Design: K-12
04.646 Seminar in Curriculum and Instruction
04.649 Practicum in Curriculum and Instruction

III. Electives Related Fields

Three (3) or four (4) courses must be selected from courses numbered 03, 04, 05, or 06, with the advice and approval of the student's advisor.

IV. The curriculum and instruction degree program requires no less than 33 semester hours.

D. Administration, Planning and Policy Degree Program (Ed.M.) The master's degree program in Administration, Planning and Policy is designed to meet the needs of those planning careers as practitioners in a variety of middle-level administrative areas in public and private educational institutions as well as community organizations and various human service agencies. The program also serves as the initial sequence of study for those planning further graduate study in administration in preparation for careers as top-level administrators, planners, researchers or theorists.

As soon as a student is admitted to the degree program, a plan of study is individually designed by the student and advisor to meet particular career goals. Please note that students seeking certification in a variety of administrative or supervisory areas, particularly in public school settings, must be certain that all courses required for a particular certification are completed.

There is a common body of knowledge which those working in the area of administration should have in order to function effectively. Therefore, four basic courses are required of all degree students and should be taken early in the program. A course in research methods including basic knowledge of the function of computers is required. In addition, each student will participate in a practicum experience as part of the degree program.

Students have the option of pursuing one or two means of completing degree requirements:

A. Complete 36 semester hours including all required courses.

B. Complete 30 semester hours including all required courses and complete a project or paper of substantial depth which would illustrate the student's expertise. A student undertaking a project or specialized paper must make a decision to do so early in the program so that he/she may work with the faculty mentor from initial status to completion. Projects and/or papers must be accepted by a faculty committee.

Students considering more advanced study in this area are encouraged to consider option B.

Please Note: Not all courses are offered every year; several are offered in alternate years only.

The programs listed below are in two strands: a program for School Administrators and a program for those engaged in Human Services Administration.

In each case, there are common course offerings.

I. *Required Courses in Administration, Planning and Policy (4)*

- 05.611 Introduction to Educational and Human Service Adm.
- 05.639 The Planning Process (same as 04.639)
- 05.614 Analysis of Educational and Human Service Organizations
- 05.622 The Principalship *or*
- 05.636 Principles of Supervision

II. *Methodology Courses*

One course in research methodology or computer literacy is required. Students pursuing graduate work beyond the Master's Degree will need to demonstrate competency in both areas for advanced degrees.

III. *Humanities and Behavioral Studies*

Two courses are required in this area and may be selected from courses beginning with the 01 prefix. The following courses are recommended: 01.552, 01.612, 01.614, 01.621, 01.624, 01.625 and 01.627.

IV. *Electives*

- 05.613 Labor Relations in Human Services
- 05.660 Citizen Participation in Education and Community Action Programs
- 05.632 The Human Service Administrator
- 05.625 Management of Human Services in School Settings
- 05.633 Educational Response to Cultural Diversity
- 05.634 Financial Aspects of Educational and Human Services Administration
- 05.635 Legal Policy in Educational and Human Services Administration
- 05.636 Principles of Supervision
- 05.649 Directed Study in Administration, Planning and Policy or any course beginning with an 05 prefix.
- 05.652 Politics of Education and Human Services Policy Making

V. *Practicum*

- 05.646 School Principal N-6
- 05.647 School Principal 5-9
- 05.648 School Principal 9-12
- 05.645 Human Services Administration

VI. *Professional Experience*

Each candidate for the degree in Administration, Planning and Policy is required to have successfully completed no less than three years of

full time employment in an educational institution or a human service agency prior to completion of degree requirements.

E. Reading and Language Degree Program (Ed.M)

I. *Prerequisite Course Requirements*
Two prerequisites for admission to the course entitled "Clinical Assessment of Reading and Language" are satisfactory completion of prior courses both in the teaching of reading in the elementary school and in the teaching of reading in the secondary school. These prerequisites may be met by satisfactory completion of the graduate courses entitled "Developmental Reading: Secondary School" and "Developmental Reading: Elementary School".

II. *Required Courses*

06.624	Acquisition of Language
06.628	Clinical Assessment of Reading and Language Disabilities
06.629	Educational Treatment of Reading and Language Disabilities
06.649	Seminar in Reading and Language
06.631	Organization and Supervision of Reading and Language Program
06.648/901/902/903	Practicum: Reading and Language Disabilities

III. *Electives*
One (1) or two (2) courses must be selected from courses numbered 01, 03, 04, or 06 with the advice and approval of the student's advisor.

IV. The Reading and Language degree program requires no less than 36 semester hours of course work including the nine (9) hours of Practicum.

The program requirements for the *Certificate of Advanced Graduate Specialization (C.A.G.S.)* in Reading and Language include:

I. *Core Requirements* - 9 Semester Hours
06.670 Issues in Reading and Language Instruction
06.671/672 Research Seminar in Reading and Language

II. *Reading and Language* - 12 Semester Hours
In consultation with the Graduate Advisor the student will select 12 semester hours of course work at the 06.650 or higher level.

III. *Electives* - 9 Semester Hours
Three (3) courses (9 sem. hrs.) must be elected from courses numbered 03, 04, 05, 06, or 07.

01.551 Statistics (3-0)3
Concentrates on both descriptive and inferential statistics in education. In descriptive statistics, the topics include central tendency, variability, correlation, and regression. Inferential statistics includes topics such as sampling and analysis of variance. Prerequisite, does not count toward graduate degree.

01.554 Issues in Philosophy of Education (3-0)3
Ideas of the great philosophers will be examined relative to topics of contemporary educational concern.

01.560 Introduction to Teaching (3-0)3
The history of teaching in our society, traditions, myths and folklore associated with various kinds of teaching, and the importance of teaching for the continuation of a literate society.

01.601 Measurement and Evaluation (3-0)3
Principles and procedures of measurement and evaluation as an integral part of instructional design.

01.612 Contemporary Issues in Education (3-0)3
Those philosophical disputes which have a direct relationship to the problems of education, namely, the school and social progress, the "open school," the validity of moral judgement, and education in the Third World.

01.614 Issues in the History and Philosophy of American Education (3-0)3
The conflicts that have emerged and shaped American educational institutions and selected issues in contemporary American education in light of their historical and philosophical origins.

01.616 Values in American Culture (3-0)3
Significant aspirations, beliefs, and behavior patterns in American culture are explored. Issues of conflict within our national identity: such as the Puritan view of our destiny, the Covenant Theory, Twain's lament over our foreign policy, the Marshall Plan and MacArthur's Japanese Constitution, the Peace Corps, Vietnam.

01.618 Ethics of Education and Human Services (3-0)3
The dynamics of American culture pose serious ethical problems for contemporary education and other human service institutions.

01.620 Theories of Learning (3-0)3
A detailed analysis of the major contemporary learning theories, both behavioral and cognitive. Areas to be covered include: attention, motivation, S-R paradigms, cognitive processes, Gestalt and field theories. Theorists studied include Bruner, Hebb, Kohlberg, Osgood, Piaget, Sears, Skinner, and Werner.

01.621 Social Psychology in Education (3-0)3
A conceptual and empirical study of social behavior within interpersonal group, organizational, and community settings, both formal and informal. The major experimental studies undertaken in the areas of attitude formation, conformity, decision making, game theory, interpersonal attraction, altruism, aggression, etc., will be analyzed.

01.622 Individual Assessment of Intelligence (3-0)3
Prerequisite: Permission of instructor.
A laboratory course in the techniques of administering, scoring, and interpreting the Wechsler Intelligence Scale for Children (WISC), Wechsler Pre-School and Primary Scale of Intelligence (WPPSI) and the Stanford-Binet Intelligence Test.

01.623 Inventiveness in Education, Human Services and Administration (3-0)3

Inventiveness is explored as a source of power integral to the survival and future of organizations and to the morale and stability of the individual working in them.

01.624 Issues in Sociology of Education (3-0)3

An intensive analysis of selected issues and problems in the sociology of education.

01.625 Organization of Schools and School Systems (3-0)3

The formal and informal social relationships of teachers, administrators, specialists, and pupils are examined for potential sources of role strain and role conflict.

01.626 Problems of Ethnic Groups in Public Schools (3-0)3

This course will: 1.) review common problems of ethnic groups from a national and local perspective; 2.) address specific areas such as academic performance, social adjustment, cultural and language adaptations; 3.) examine ways teachers and administrators can enhance the learning process for minority youngsters.

01.627 Interpersonal Relations in Education and Human Services (3-0)3

This course examines the professional-client relationship and the authority of administrators and professionals from a social-psychological perspective.

01.631 Cognition and Instruction (3-0)3

The reasoning and thinking processes and the importance of problem solving as methods of instruction.

02.550 Reading Education: Elementary (3-0)3

A critical analysis of fundamental issues and principles in the teaching of reading, including all phases of the elementary reading program; current materials and approaches for diagnostic and developmental teaching of reading. Evaluation of research in reading.

02.551 Mathematics Education: Elementary (3-0)3

New approaches in the curriculum and teaching of mathematics in the elementary school; analysis and use of current materials, multimedia approaches, and inductive and problem-solving techniques.

02.552 Social Studies and Science Education (3-0)3

Selection and organization of context for the teaching of the social sciences and new approaches in the curriculum and teaching of science in the elementary school. Theories and strategies used in new programs, use of current materials, multimedia approaches, and the use of procedures to encourage thinking, discovering and creativity.

02.553 Language Education - Elementary (3-0)3

Approaches in the curriculum, teaching and assessment of the language arts in the elementary school will be analyzed and various techniques of instruction will be studied.

02.554 Analysis of Teaching (3-0)3

Practical processes for instructional designs. The major classifications of learning outcomes are introduced and are interrelated with clearly defined performance objectives, teaching strategies, and evaluation techniques. Development of the individual lesson plan. Classroom management and control.

02.555 Literature for Children (3-0)3

An in-depth study of assorted genres of literature, the development of a literature program integrated with a variety of curriculum areas for elementary school aged children in a multi-ethnic, multi-cultural environment.

02.556 Reading Disabilities **(3-0)3**
An advanced course in the analysis and remediation of reading disabilities which will explore the use of critical diagnostic tools and specialized materials using the diagnostic-prescriptive method of teaching. The problem of dialectical differences and the special reading problems of bi-lingual youngsters.

02.557 Reading Education: Middle/Secondary **(3-0)3**
The development of adult reading skills in the middle and secondary school by using these skills in the content areas. Individualizing content reading to suit the needs of students.

02.558 Measurement and Evaluation **(3-0)3**
The principles and procedures of measurement and evaluation essential to excellence in teaching. The main theme is that evaluation is an integral part of instructional design.

02.560 Curriculum Development: Middle/Secondary **(3-0)3**
Analysis, comparison, and evaluation of a variety of models for curriculum development; evaluation of present curricula in middle and secondary schools, and development strategies for implementing curriculum reform.

02.564 History of American Education **(3-0)3**
An analysis of the development of educational thought and practice in the United States within the context of American social, cultural, economic, and intellectual history.

02.565 Developmental Psychology **(3-0)3**
A study of the concepts and methodologies of the major theoretical systems (Genetic-Structural — Neo-Behavioristic) in Developmental Psychology; and the application of these concepts in a variety of educational settings.

02.XXX Curriculum and Teaching in Major Area **(3-0)3**
An analysis of the content, methods, materials, and management techniques used in each major area of the secondary school. Simulation and self-evaluation in teaching. Observation and participation in secondary schools.

02.578 Practicum: Teaching Elementary **(12-0)12**
Prerequisites: 02.550, 02.551, 02.552, 02.553, 02.554, 02.558, 02.565.
Full time apprentice teaching in the public elementary schools under the supervision of qualified teachers, principals, and faculty of the College of Education.

02.579 Seminar in Elementary Education **(2-0)2**
Preparation for apprentice teaching.

02.XXX Practicum: Teaching Major Area: Secondary **(12-0)12**
Prerequisites: 02.557, 02.558, 02.565, 02.XXX.
Full time apprentice teaching in the public secondary schools under the supervision of qualified teachers, department chairpersons, principals, and faculty of the College of Education.

02.596 Seminar in Secondary Education **(3-0)3**
Familiarization of the apprentice teacher with the secondary school, its administration, activities, operations, services, personnel interactions, purposes and pressures.

03.601 LOGO **(3-0)3**
Participants will learn to program in LOGO and will explore issues related to its use in elementary and junior high school classrooms. Novices will be introduced to programming through turtle graphics, while more advanced students may explore list processing and other applications of LOGO.

03.602 PILOT and Other Authoring Languages **(3-0)3**
The use of text authoring languages for the creation of computer assisted instruction. Students will design sets of CAI lessons for use in the elementary and secondary classroom.

03.612 Software Applications I (3-0)3
Use of computer software to support instruction and to provide instruction. Students will identify several management and/or instructional tasks they normally perform; select appropriate software; develop a plan to use the software; and submit written and oral reports of their progress and future plans.

03.613 Software Applications II (3-0)3
Prerequisite: 03.612 or Instructor Permission
Selection and acquisition of computer equipment and software; how equipment might be distributed and used most effectively to support instruction within and among schools.

03.617 Design of Instructional Material for Computers (3-0)3
Instructional design principles in the development of software to be integrated with and enhance present and future curricula. Each student will have an opportunity to lay out a design for lesson models in his/her area of specialization. Experience with programming BASIC is desirable.

03.633 Curriculum Development for Interactive Media (3-0)3
Prerequisites: 03.660, 04.638, 07.650.
For the advanced student, the course will focus on curriculum building for interactive media (computers and interactive video).

03.651 Technology and Learning Environments (3-0)3
Curriculum policies and instructional issues in the uses of technology for instruction. Students will develop a model of the technological classroom.

03.660 Television: A Tool of Instruction (3-0)3
An historical review of the uses of television for instruction in the last 30 years. Instructional design, utilization in the classroom, and criteria for evaluation of programming being used in the schools *now*.

03.652 Design of Instructional Materials for Interactive Video (3-0)3
Prerequisites: 03.660, 07.560
For the student who has previously developed a familiarity with instructional television and instructional computing, the course will extend the principles of instructional design to videodisc and other forms of interactive video.

03.690 Evaluation of Technological Curriculum (3-0)3
Formative and summative evaluation of television and computer software for instructional purposes.

04.541 Newspaper in Education (3-0)3
This workshop is designed to assist all teachers (K-Adult Education) in any subject matter discover techniques for using the newspaper in the classroom. Content will include special interests such as reading, career education, and conflicts over First Ammendment issues in education.

04.612 Innovation and Change in the English Curriculum (3-0)3
A review of past and future English curriculum developments over the last quarter century: including censorship, back to basics, minimal-competency testing, open classroom, grouping, values clarification, sophisticated media, the influence of the paperback, and the evaluation of teachers.

04.617 Economic Education I (3-0)3
Discussion of selected concepts of the American economic system and development of teaching materials using these concepts.

04.618 Economic Education II **(3-0)3**
Economic concepts to be examined via lectures, video tapes and computer software are unemployment, inflation, taxes and Reaganomics. Participants will develop teaching materials for use in the subject and at the grade level they are teaching.

04.619 Economic Education III **(3-0)3**
Prerequisite: Instructor Permission.
Advanced curriculum development in economic education.

04.621 Problems, Innovations and Change in the Mathematics-Science Curricula **(3-0)3**
Investigation of educational issues and problems in the mathematics or science area. Evaluative examination of instructional techniques and teaching materials in the curriculum revision projects of these disciplines.

04.622 Teaching Geometry **(3-0)3**
Exploration of geometric concepts through investigation and a search for pattern. Hands-on experiences with manipulatives which relate to the topics recommended in the mathematics curriculum of today's schools.

04.623 Teaching Science **(3-0)3**
Current science teaching strategies and materials and analysis of the purposes and products of these techniques as employed in secondary schools.

04.626 Reasoning, Thinking, Problem Solving/Math **(3-0)3**
Research, methodology and new curriculum materials for teaching reasoning and thinking skills and in the mathematics curriculum.

04.627 Diagnostic and Remedial Measures in Mathematics **(3-0)3**
Students will identify and develop remedial and instructional strategies for use in helping children with difficulties in learning mathematics.

04.632 Innovations and Change in Social Studies Teaching Methodologies **(3-0)3**
Methodologies used in the teaching of the social studies with emphasis on the inquiry method. Students will develop and demonstrate a teaching methodology for a specific project in the social studies.

04.634 Teaching and Learning About Aging **(3-0)3**
Aging and age related issues, and a variety of methods and resources for bringing this timely and important topic into the classroom at all grade levels.

04.635 Program Planning for the Gifted and Talented **(3-0)3**
Gifted and talented program development: determination of need, cost and funding alternatives, identification strategies and curricular options, public relations, staff training, and program evaluation. Participants will examine current literature in the field, assess their own school or system needs for gifted and talented education, and develop a plan for initiating a cost-effective program.

04.637 Curriculum Design: K-12 **(3-0)3**
A review of state mandates which, by law, shape the curriculum of the school, an examination of "new" curricula and their source, as well as the development of a rationale for curriculum design and an evaluation of the personnel and techniques by which these curricula can be developed.

04.638 Theory and Research in Curriculum **(3-0)3**
A study of the nature of the educational experience and the creation of curricula. The contemporary theorists' views of content, concept, experience, and curriculum development.

04.639 The Planning Process (3-0)3
Methods and theories of planning in educational and non-profit organizations. Setting goals and objectives, establishing priorities, undertaking a needs assessment for various kinds of short and long range planning.

04.640 Program Evaluation (3-0)3
The historical emergence of program evaluations will be considered, the evaluation tasks will be identified and the policy issues attendant to evaluation will be examined.

04.645 Directed Study in Curriculum and Instruction (3-0)3
Prerequisite: Permission of Chairperson of the Faculty.
Through frequent consultation with the instructor, the student will investigate and define a problem for research in curriculum and instruction, and will present the findings in a significant paper. The directed study may not be substituted for a required course.

04.646 Seminar in Curriculum and Instruction (3-0)3
Prerequisites: 04.637, 04.638, 04.639.
Contemporary research in the field and on research being done on national and international curriculum projects. The student will apply his/her research knowledge to individual investigations and analysis to give evidence of expertise in his/her field.

04.647 Seminar: Issues in Developing Career Awareness Programs (3-0)3
The rationale for, the issues of content and implementation of, and the impact of governmental agencies on the establishment of career awareness programs. Literature will be reviewed and the concepts of career awareness will be examined to develop a realistic definition and a proposed program of career awareness.

04.648 Seminar: Issues in Basic Skills Instruction (3-0)3
An investigation and evaluation of the call for a return to "basics". Consideration of the causes of renewed interest in "basics" and a review of current instruction in the basic skills.

04.649 Practicum: Curriculum and Instruction (3-0)3
Prerequisite: Permission of Chairperson of the Faculty.
Supervised clinical experience. An opportunity to apply the skills and knowledge of curriculum development and evaluation of instruction

04.651 Issues in Minumum Competency (3-0)3
Origins, present status and future direction of the minimum competency movement. Political, technical, legal and instructional issues in design and implementing competency programs.

04.652 Models of Teaching (3-0)3
Examination and evaluation of models of teaching and observation; identification and evaluation of teaching strategies.

04.657 Early Childhood Education (3-0)3
Recent research and program planning requirements associated with implementing an early childhood program in schools and/or the community.

04.660 Schools in the 90's (3-0)3
What will they be like? How will the available technology be used in them? Will the use of technology alter the configuration of the school day, year, purpose, support? Students will be expected to design a model of the "school" in the 90's, with theoretical rationale and practical justification for the model.

04.661 Politics of Curriculum Change: Control of Educational Programs (3-0)3
Analysis of various pressure groups that attempt to exert influence on the school curricula. Students will investigate the ideologies, mechanisms, and impacts of various political forces at the local, regional and national levels.

04.662 Issues in Teacher Education **(3-0)3**

Historic issues in teacher education: such as governance, the intellectual requirements, context and content of teacher education, amounts of academic preparation, the "apprentice" period and evaluation of teachers will be considered in the light of research and practice. In addition, new issues of management, competence-based and field-based programs, accountability, public relations, labor/professional ethics and peer evaluation will be considered.

04.677 Action Research **3-6-9**

Prerequisite: Permission of Dean.

This course is required in the experienced teachers' option of the Curriculum and Instruction program. It provides the opportunity to do on-site research related to the student's special interest.

05.611 Introduction to Educational and Human Service Administration **(3-0)3**

Explores how to be and what it means to be an administrator. "Grasps" of self in role and perception are related to ethical commitment.

05.613 Labor Relations in Education and Human Service Organizations **(3-0)3**

An introductory course on the theory of collective bargaining and its application and how decisions are made in such areas as wages, hours and conditions of work.

05.614 Analysis of Educational and Human Services Organizations **(3-0)3**

An examination of various models of organizational analysis used to explain events and relationships in educational and human service institutions. Each student will develop a case study and analysis using organizational theory.

05.615 Legal and Ethical Frameworks for Administration of Educational and Human Service Organizations **(3-0)3**

Participants study traditions which underlie "organized caring for others" and their reflection in current legal and administrative framework which make caring for others possible.

05.616 Law: Institute I **(3-0)3**

For board members, chief school officers and their assistants, principals and faculty. To remove fear of law, participants learn how to : 1) research current law; 2) think like lawyers, judges and legislators; 3) practice "preventive law"; 4) scan for problems and potentials in institutions; 5) make plans which influence the positive growth of law.

05.617 Law: Institute II **(3-0)3**

Prerequisite: Permission of the Instructor.

Advanced tutorial work.

05.618 Law: Institute III **(3-0)3**

Prerequisite: Permission of Instructor.

Further tutorial work.

05.622 The Principalship **(3-0)3**

Participants consider not only "how to be a principal" in giving direction to an organization but what it means, ethically and personally, to be one.

05.632 The Human Service Administrator **(3-0)3**

Explores concepts through lives of persons who played administrative roles (biographies, literature, history) with attention to "turning points" (new hopes, places, organizations, perspectives).

05.633/02.559 Educational Response to Cultural Diversity, (3-0)3

The role of schools in a culturally pluralistic industrial society. The response of educational institutions to diverse ethnic groups in earlier times. Recent legislation on public education will be examined during the latter part of the semster.

05.634 Financial Aspects of Educational and Human Service Administration (3-0)3

Examines how moral and financial resources are marshalled to meet needs. Includes legal, economic and organizational analysis, program definition, budgeting, management and evaluation.

05.635 Legal Policy in Educational and Human Services Administration (3-0)3

Understanding and research of issues and resolutions which define organizational activity. Ethical and creative practice of "preventive law".

05.636 Principles of Supervision (3-0)3

The interdisciplinary foundations of supervision: the function of theory, research on change, individual and group relationships in organizations, staff influence processes, talent utilization, and evaluation.

05.637 Personnel Administration and Educational Policy (3-0)3

Considers ideal "starting points" for a vision of personnel administration, including legal traditions, conscience and "shepherding," and their expression in a detailed model personnel "system".

05.638 Issues in Staff Development (3-0)3

Techniques for assessing staff needs, programs designed to improve staff performance, and the design and strategy necessary to insure productive in-service education and staff development.

05.639 The Planning Process (same as 04.639) (3-0)3

05.645 Practicum: Human Services (3-0)3

Prerequisites: 05.611, 05.614, 05.636, 05.639 and Permission of Coordinator.

Supervised clinical experience. Students acquire practical administrative experience in a hospital, social service agency or similar institution under the direct supervision of both an agency administrator and a college faculty member.

05.646 Practicum: Elementary School Administration (3-0)3

Prerequisites: 05.611, 05.614, 05.622, 05.639, and Permission of Coordinator.

Supervised clinical experience in an elementary school under the direction of both the school administrator and a college faculty member.

05.647 Practicum: Middle School (3-0)3

Prerequisites: 05.611, 05.614, 05.622, 05.639, Permission of Coordinator.

Supervised clinical experience in an elementary school under the direction of both the school administrator and a college faculty member.

05.648 Practicum: Secondary School (3-0)3

Prerequisites: 05.511, 05.622, 05.639, Permission of Coordinator.

Supervised clinical experience in a secondary school under the supervision of both the school administrator and a college faculty member.

05.649 Directed Study in Administration Planning and Policy **(3-0)3**

Prerequisite: Permission of Faculty Chairperson.

Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. The directed study may not be substituted for a required course.

05.650 Life Portraits of American School Systems and Human Service Organizations **(3-0)3**

Explores schooling and human services issues, including constitutional rights, curriculum, personnel, and finance, through contemporary law cases. Simulation of problem-solving and creative roles.

05.651 Education and the New Right **(3-0)3**

Forms of leadership by which one may relate to New Right concerns as seen in historical figures such as Abraham Lincoln and Martin Luther King.

05.652 Politics of Education and Human Services **(3-0)3**

To understand the function of schools and human service agencies we must look beyond their perceived professional and philanthropic function and view them as political systems. We will focus on the political conditions and forces that continue to shape these systems and their programs.

05.660 Citizen Participation in Education and Community Action Programs **(3-0)3**

Citizen participation increases in times of expectation, it declines in times of despair. What causes these periods of fluctuation in participation? How and why are citizen groups organized? What gains can they make by organizing? What are the most productive techniques for capitalizing on this interest?

05.661 Parents and Schools **(3-0)3**

Understanding and improving the relationships between parents and schools can be an important factor in improving the quality of education. A study of pertinent theoretical and research literature as well as specific applied situations, such as effective approaches for involving "hard to reach" parents.

05.665 Professionalization of Educational Careers **(3-0)3**

The changing careers of teachers and administrators in our society. The development and expansion of colleague collaboration through educational associations, team-teaching, and informal social interaction. Professional responses to citizen pressures for teacher accountability and drastic reduction in school expenditures.

06.601 Developmental Reading: Elementary School **(3-0)3**

The acquisition and development of reading skills by children in the elementary school. Special emphasis will be placed on the analysis of new curricula, and on methods and materials designed to facilitate the child's reading development.

06.602 Developmental Reading: Secondary School **(3-0)3**

The continuum of reading skills from childhood through adulthood will be considered, with major emphasis on the acquisition and development of advanced reading skills by students in the secondary school.

06.621 Literature for Children **(3-0)3**

The course will examine the importance of literature in the growth of the child, will consider ways of assisting children in developing a taste for the best literature, and will pursue strategies for organizing, projecting and evaluating a literature program.

06.622 Literature for Young Adults (3-0)3
The major emphasis of the course will be discussion and analysis of the goals of a literature curriculum, and the exploration of various methods for achieving these goals.

06.623 Issues in Children's Literature (3-0)3
Participants in this course will consider literature for children from several thematic approaches including materials which deal with war, sex, death and aging, divorce, minorities and the female. Readings, discussion and use of books in the literature program will be components of the course.

06.624 Acquisition of Language (3-0)3
This course investigates the process by which language is acquired. The pertinent research, both historical and current, will be critiqued, methods of investigating and analyzing language studies, and implications of language development in the acquisition of reading and language skills will be discussed.

06.626 Teaching Study Skills, Grades 4-14 (3-0)3
An examination of research and successful teaching practices in skills and processes associated with the acquisition, assimilation, and expression of new information and ideas. The course is designed to help teachers improve student listening skills, textbook reading, vocabulary, library use, note-taking, comprehension, reporting, memory, test-taking, motivation, and self-concept.

06.627 Etiology of Reading and Language Disabilities (3-0)3
Considers the cause and theories of reading and language disabilities. Physical, neurological, genetic, cognitive, perceptual and psychological factors are studied.

06.628 Clinical Assessment of Reading and Language Disabilities (3-0)3
Prerequisites: 06.601, 06.602,
(or their equivalents); a teaching certificate is required.
The selection and use of appropriate procedures to make an adequate clinical and educational diagnosis. This includes the assessment of function and dysfunction in factors associated with language development: receptive, expressive, writing, reading; and the administration and interpretation of individual and group tests of perceptual, motor, and conceptual functioning in reading and language.

06.629 Educational Treatment of Reading and Language Disabilities (3-0)3
Prerequisites: 06.628, teaching certificate.
Students will be expected to develop realistic corrective programs based on the interpretation of academic, perceptual, motor, and language diagnostic assessment instruments. These programs will include selecting the proper strategies of instruction, the most productive materials, and establishing a framework of time and of evaluation for the programs.

06.630 Reading, Listening and Thinking (3-0)3
An exploration of research and theory in language-thought relationships with emphasis on the improvement of higher mental processes through instruction in listening and reading.

06.631 Organization and Supervision of Reading and Language Programs (3-0)3
Organization and supervision of a reading-language program, evaluation of classroom instruction, selection of reading-language materials, coordination of the developmental program with remedial/corrective offerings, techniques of in-service education for various professional groups within a school system.

06.647 Directed Study in Reading and Language (3-0)3
Prerequisite: Permission of Reading and Language Coordinator.

Through frequent consultation with the instructor, the student will investigate and define a problem for research in Reading and Language, and will present the findings in a significant paper. The directed study may not be substituted for a required course.

06.648 Practicum: Reading and Language Disabilities **3-6-9**
Prerequisites: 06.628, 06.629, and
Permission of Reading and Language Coordinator.
Supervised clinical experience in a school or clinical setting. (NOTE: Open to matriculated students only.)

06.649 Seminar in Reading and Language **(3-0)3**
Prerequisite: Permission of Instructor.
A final course on the national and international research in reading and language and the pertinence and proposed implementation of research findings to instruction. The various roles of the reading supervisor or director.
(NOTE: Open to matriculated students only.)

06.650 The Politics of Literacy Instruction **(3-0)3**
Literacy in the United States and the developed and developing nations of the world. Various techniques utilized in literacy instruction will be critiqued according to their success or failure from a political and social viewpoint.

06.651 Reading Comprehension and the Composing Process **(3-0)3**
An examination of the similarities (and dissimilarities) between reading comprehension and the composing process. Programs which have effectively combined instruction in reading and writing are examined. Students devise strategies for teaching both reading and writing together for greater effectiveness.

06.653 Listening Skills Instruction **(3-0)3**
The purposes of this course are to: 1) examine recent research in listening, 2) evaluate tests and instructional materials, and 3) assist teachers in the preparation of materials for their own classes (kindergarten through college level).

06.664 History and Development of Reading Instruction in the United States **(3-0)3**
A retrospective study of the methodology of materials of reading instruction will be undertaken in conjunction with a review of the social, economic and political climate which gave rise to the procedures utilized in each era and which, in turn, have influenced current theories and models of reading and literacy instruction.

06.669 Advanced Clinical Assessment - Reading and Language Problems **(3-0)3**
Prerequisite: 06.628 or equivalent.
The place of diagnostic tests in the total testing program, including achievement, intelligence, criterion-referenced and informal evaluation will be studied, and a constellation of tests considered supplementary or auxilliary to the main diagnostic reading instruments will be critiqued. Newer techniques, including Normal Curve Equivalents, for handling group data for Federal and State reports in funded reading programs will be studied as to their effectiveness in reading program evaluations and report writing.

06.670 Issues in Reading and Language Instruction **(3-0)3**
Prerequisite: Permission of Instructor.
Students will study such topics and issues as the subskills vs. holistic theory of the reading process, the spinoffs from the competency testing basic skills trends, bilingualism as related to reading instruction, uses of electronic media in the schools, the newer types of print materials, relationship of learning disability instruction to remedial reading, and other emerging trends.

06.671, 672 Research Seminar in Reading and Language (3-0)3
Prerequisite: Permission of Reading and Language Coordinator. For CAGS students.
Papers in areas related to problems in reading and language. An examination and analysis of current research at the national and international levels will be conducted, and methods of implementation and dissemination of pertinent results will be discussed.

07.701 Seminar in Data Analysis (3-0)3
Prerequisite: An elementary statistics or research methods course satisfactory to the Program Faculty.
Quantitative methods including bivariate and multivariate techniques necessary to hypotheses testing in educational research. The course will require the use of computer software for statistical analysis. The selection of appropriate analysis, interpretation of results, and methods of reporting will be emphasized.

07.702 Seminar in Research Methodology and Design (3-0)3
Prerequisite: 07.701 or acceptable substitute.
Methods of data collection suitable for answering a variety of educational research questions. The course will consider both qualitative and quantitative strategies for research and evaluation needs; however, the quantitative methodologies for descriptive, correlational and experimental questions will be emphasized.

07.703 Seminar in the Design of Research Projects (3-0)3
For graduate students in the early stages of planning a dissertation, this seminar is geared to the development of research proposals. Students will have an opportunity to search the literature in a field of their interest, develop research questions and formulate testable hypotheses or a suitable research plan. Methods of data collection and analysis will be discussed as they relate to the research questions and plan.

07.707 Writing For Professional Publication (3-0)3
This course will assist students: 1) to identify professional journals appropriate for publication of material in their fields, 2) to analyze the type of articles used, and 3) to prepare research, as well as information articles, clearly and concisely for publication.

07.640 Research Methods (3-0)3
The focus of this course is the construction of statistically testable hypotheses, the design of research studies appropriate to the hypotheses, and the application of statistical tests appropriate to the research designs. Evaluation of published research in accordance with established criteria will be required.

07.650 Computer Literacy (3-0)3
An introduction to the computer in an educational setting. In addition to acquiring and understanding of how computers work, knowledge of hardware and software and familiarity with computer terminology, participants will explore current instructional uses and the power and potential of the computer in developing thinking and problem-solving skills.

COLLEGE OF ENGINEERING

DEAN: ALDO M. CRUGNOLA: A.B., Boston University; M.S., Northeastern University, Sc.D., Massachusetts Institute of Technology

ASSISTANT DEAN: RICHARD MINESINGER, B.S., Princeton University; M.B.A., Case Western Reserve University

DIRECTOR FOR GRADUATE STUDIES: JOHN A. McELMAN, B.S., M.S., Northeastern University; Ph.D., Virginia Polytechnic Institute

The education of engineers in state-of-the-art areas of advanced technology and the University's committment to national and regional economic development are the major premises upon which the graduate programs in the College of Engineering are based. These programs are intended to produce engineers whose education not only develops expertise in the design, development and production of products, but also an understanding of the management involved in the creation of new products, companies and service organizations. Thus, the graduate programs in engineering are intended to educate engineers capable of keeping abreast with the rapidly changing technology that characterizes the high technology economy of the Northeast. The programs lead to degrees of Master of Science in Engineering, Doctor of Philosophy and Doctor of Engineering.

Master of Science in Engineering (M.S. Eng.)

The master's degree is awarded in the following fields:

Chemical Engineering
Civil Engineering
Environmental Studies
Mechanical Engineering
Electrical Engineering
Systems Engineering
Computer Engineering
Plastics Engineering: Coating and Adhesives Option, Synthetic Fiber Option
Paper Engineering
Energy Engineering: Fission, Fusion, Solar, Geothermal Options

Master of Management Science (M.M.S.)

The master's degree is awarded in the following field:

Manufacturing Engineering

DOCTOR OF PHILOSOPHY (Ph.D.)

Doctor of Philosophy degrees are awarded in selected fields in the College of Engineering in conjunction with the College of Pure and Applied Science. Degrees are currently offered in the following fields:

Energy Management
Engineering Mechanics
Environmental Studies
Plastics Engineering

DOCTOR OF ENGINEERING (D.Eng.)

The Doctor of Engineering degree is a professional degree intended to equip the student for the practice of engineering at the highest professional level and in an environment that is characterized by rapid change and ever increasing complexity. It equips the student to do in-depth work in an area of specialization, but also provides him/her with the breadth necessary for assuming positions of leadership in a research organization, in industry, or in public administration. To meet this objective the course of study is divided into two parts: One part reflects the area of engineering specialization; the other part deals with engineering leadership and management. Content and organization of the first part are determined by each department, and are described in the departmental sections. Content and organization of the second part is common to all the programs and is administered at the college level. Doctor of Engineering programs currently exist in the following departments:

Electrical Engineering
Mechanical and Energy Engineering
Plastics Engineering

DEPARTMENT OF CHEMICAL ENGINEERING

DEPARTMENT CHAIRPERSON: KARL J. SLADEK, *Professor;* B.S., M.S., Sc.D., Massachusetts Institute of Technology.

GRADUATE COORDINATOR: DOMINICK A. SAMA, *Professor;* S.B., S.M., Sc.D. Massachusetts Institute of Technology.

Faculty:

Huan-Yang Chang, *Professor;* B.S., Southwest Associated University, China; M.S., University of Rhode Island; Ph.D., Iowa State University.
Ning Hsing Chen, *Professor;* B.S., National Chekiang University, China; B.Ch.E., Polytechnic Institute of New York; M.S. University of Missouri; D.Ch.E., Polytechnic Institute of New York.
Alfred A. Donatelli, *Associate Professor;* B.S., Lowell Technological Institute, Ph.D., Lehigh University.
H. William Flood, *Distinguished Visiting Professor;* B.S., Professional Degree (M.S. Equivalent), University of Missouri, Rolla; P.E. (Mass).
Charles J. Higgins, *Professor;* B.S. Lowell Technological Institute, P.E. (Mass.).
Norwood H. Keeney, Jr., *Professor;* B.S., Trinity College; M.S., University of Maine; Ph.D., University of Manchester, England; P.E. (New Hampshire).
Steven M. Slater, *Assistant Professor;* B.S., M.S., Sc.D., Massachusetts Institute of Technology.
John W. Walkinshaw, *Associate Professor;* B.S., M.S. M.S., Lowell Technological Institute; Ph.D., Victoria University, Manchester, England.

MASTER OF SCIENCE IN ENGINEERING DEGREE PROGRAM

The graduate program in Chemical Engineering is designed to provide the opportunity for graduate students to study the fundamentals and applications of chemical engineering principles, and to carry out independent research.

Combined B.S./M.S. Eng. Program-Chemical Engineering

See Undergraduate Catalog.

Admission Requirements

The Chemical Engineering Department will consider students for enrollment in the program of graduate studies who have a Bachelor of Science degree in Chemical Engineering from a recognized college. Those with degrees in other areas, such as Biology, Chemistry, etc., are also admissible to the graduate program. However, during their course of study, they will be required to take the undergraduate courses in which they are deficient. It is highly recommended that such students complete 4 years of Mathematics through Differential Equations, and 1 year each of Organic Chemistry and Physical Chemistry, prior to enrolling in the graduate program. Generally, such students require two to three years to complete the requirements for the M.S. degree in Chemical Engineering.

Credit Requirements

A minimum of 30 semester hours of graduate course work and thesis, excluding seminar, will be required for all graduate students enrolled in the Department of Chemical Engineering. Each student shall enroll in at least two semesters of Seminar during the period of thesis research.

Plan of Study

Each student shall file a plan of study with the Department Chairman and Graduate Coordinator. This form will contain a listing of the courses which will make up his/her program. Any changes must have the approval of the Department Graduate Committee.

Core Curriculum

The core curriculum in Chemical Engineering consists of at least 12 semester hours in the following courses:

10-503	Mass Transfer Operations I	(3-0)3
10-509	Mathematical Applications in Chemical Engineering	(3-0)3
10-514	Advanced Process Optimization	(3-0)3
10-517	Mass Transfer Operations II	(3-0)3
10-520	Advanced Chemical Engineering Thermodynamics	(3-0)3
10-528	Advanced Transport Phenomena	(3-0)3

Of the remaining 12 credits of course work, 6 to 9 credits should be in Chemical Engineering as described in the catalog, and 3 to 6 hours may be in 500 series courses in Mathematics, Chemistry, Engineering, etc. Technical

electives must have the approval of the departmental Graduate Committee. In unusual cases, graduate credit may be given for 400 level courses in the Department of Chemical Engineering as approved by the departmental Graduate Committee and/or the Graduate Coordinator.

Thesis

Each student will be required to undertake a 6 semester-hour thesis. All students will defend their thesis when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis s/he will be required to submit to the staff of the Department a brief monthly report, showing progress of his/her thesis and approval by his/her advisor.

Courses of Study

10-501 Paper Industry Process Analysis **(3-0)3**

Prerequisites: Permission of Instructor

Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification and mechanical processing of fiber and sheet formation. Chemical Engineering Theory is applied to the analysis of these operations.

10-502 Principles of Chemical Engineering **(3-0)3**

Prerequisite: Permission of Instructor

An introduction to chemical process engineering for non-majors, such as chemists and biologists. Covers material and energy balances, thermal properties and flow in pipes. Processes are illustrated using a variety of home work assignments.

10-503 Mass Transfer Operations I **(3-0)3**

Prerequisite: Permission of Instructor

Detailed coverage of the fundamentals of separation processes of absorption and extraction. Degrees of freedom, phase equilibrium diagrams, graphical techniques, molecular diffusion, interphase mass transfer, mass transfer and simultaneous chemical reaction. Design principles for multi-stage countercurrent contactors and continuous differential contact columns.

10-504 Process Calculations of Paper and Pulp Processes **(3-0)3**

Prerequisite: Permission of Instructor

Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

10-506 Colloid Chemistry for Chemical Engineers **(3-0)3**

Prerequisite: Permission of Instructor

Colloid chemistry principles; zeta potential and its applications; specific problems involving surface chemistry and physics.

10-509 Mathematical Applications in Chemical Engineering **(3-0)3**

Prerequisite: Permission of Instructor

Application of ordinary and partial differential finite difference equations, integral transforms and generating functions in the solution of chemical engineering problems is emphasized with numerous real life examples.

10-514 Advanced Process Optimization **(3-0)3**

Prerequisite: Permission of Instructor

An advanced study of modern optimization techniques having applications in process economics, process analysis, process dynamics, process kinetics and process design; methods such as linear, non-linear, geometric, dynamic programmings, discrete and continuous maximum principles.

10-516 Microprocessor Control (2-3)3

Prerequisite: Permission of Instructor

Single board computers and single chip controllers and how they are used in chemical process control.

10-517 Mass Transfer Operations II (3-0)3

Prerequisite: Permission of Instructor

Fundamentals and modeling techniques for the separation process of distillation. Flash distillation, batch distillation, multicomponent distillation. Shortcut design method, Lewis-Matheson method, Thiele-Geddes method, Wang-Henke method, other methods. Optimization.

10-518 Microprocessor Control II (2-3)3

Prerequisite: 10-516

Programming methods for using minicomputers as process controllers; interfacing requirements and communications. Laboratory projects include both software and hardware.

10-520 Advanced Thermodynamics (3-0)3

Prerequisite: Permission of Instructor

The central theme of this course is the use of the Second Law of Thermodynamics to reduce energy consumption in operations and processes in the chemical industry. Lost work analysis techniques are developed for the evaluation of thermodynamic processes. Areas of study include power cycles, refrigeration and distillation.

10-521 Introduction to Environmental Engineering (3-0)3

Prerequisite: Permission of Instructor

Introduction to air, water, and toxic (hazardous) wastes. Defining the assessment parameters necessary to resolving environmental problems, process calculations on pollution abatement systems.

10-522 Computer-Aided Chemical Process Design (3-0)3

Prerequisite: Permission of Instructor

Process synthesis, definition, and characterization. Introduction to modular process stimulation packages such as FLOWTRAN and ASPEN PLUS™. Recycle and tear stream analysis. Stream convergence. Unit operation models. Flowsheet manipulation. Data records and physical property estimation techniques.

10-523 Electronic Materials Processing (3-0)3

Prerequisite: Permission of Instructor

Materials processing methods in electronics and related industries; crystal growth, diffusion, etching, epitaxy, ion implantation, lithography, contamination control, and other topics.

10-528 Advanced Transport Phenomena (3-0)3

Prerequisite: Permission of Instructor

An advanced study of the mechanism of momentum, heat and mass transfer. The equations of continuity, motion and energy are used to examine steady and unsteady state processes. Considerable emphasis is placed upon solutions to problems.

10-529 Process Integration for the Efficient Use of Energy (3-0)3

Prerequisite: Permission of Instructor

A critical study of the integration of heat and power requirements in chemical process plants. Topics to be studied include steam balances, heat pumps, heat exchangers, and heat recovery network design.

10-530 Advanced Process Dynamics (3-0)3

Prerequisite: Permission of Instructor

An introduction to some of the common control strategies applied to the design of complex chemical process control systems.

10-601 Chemical Engineering Seminar (1-0)1

10-602 Chemical Engineering Seminar **(1-0)1**
Required of all graduate students.

10-651 Selected Topics in Chemical Engineering **(3-0)3**

10-652 Selected Topics in Chemical Engineering **(3-0)3**
Advanced topics in the various fields of Chemical Engineering. Content may vary from year to year to reflect contemporary applications of chemical engineering.

10-701 Graduate Research in Chemical Engineering **(0-9)3**

10-702 Graduate Research in Chemical Engineering **(0-9)3**
Every graduate student is required to perform research work done under the supervision of a senior chemical engineering staff member. This thesis or project must be approved by an examining committee appointed by the Department Chairman.

10-751 Advanced Projects In Chemical Engineering **(0-9)3**
Prerequisite: Permission of Department
Special projects laboratory undertaken by a student to expand his/her knowledge in specific fields not necessarily related to his/her thesis. Content of project, hour assigned and supervisor must be approved by the Department Chairman.

PROGRAM IN PAPER ENGINEERING

Faculty:

Charles J. Higgins, *Professor;* B.S., Lowell Technological Institute, P.E. (Mass.).
Norwood H. Keeney, Jr., *Professor;* B.S. Trinity College, Hartford; M.S., University of Maine; Ph.D., University of Manchester, England, P.E. (New Hampshire).
John W. Walkinshaw, *Associate* Professor; B.S., M.S., M.S., Lowell Technological Institute, Ph.D., Victoria University of Manchester, England.

Master of Science in Engineering Degree Program

This program provides advanced study and research training in paper engineering and allied subjects, with specific application to the paper industry. A BS/MS program in Paper Engineering, similar to that in Chemical Engineering, is also available.

Admission Requirements

The Paper Engineering Department will consider applicants in the following categories:

1. Graduates of the University of Lowell Chemical Engineering (Paper Option) program.
2. Graduates in Paper Engineering or Paper Technology from other universities.
3. General B.S. or M.S. graduates in engineering or chemistry with no previous training in paper engineering.

Credit Requirements

A minimum of 30 graduate credits excluding seminar is required to fulfill the requirements of a master's degree in Paper Engineering, delineated as follows:

A minimum of 12 credits in graduate Paper Engineering courses chosen from the courses outlined below in the 11-series.

A minimum of 12 credits in approved technical electives, i.e., technical subjects in the 500 series, or selected 400 courses in Chemical Engineering with approval of Graduate Coordinator and/or departmental Graduate Committee.

The following Research and Seminar courses:

11-701, 702	Research	(0-9)3, (0-9)3
10-601, 602	Engineering Seminar	(1-0)1, (1-0)1

Each student shall enroll in 10-601, 602, Engineering Seminar for two semesters during the period of thesis research. Additional undergraduate subjects may be required of students who have deficiencies in their prior training.

Plan of Study

Each student shall file a plan of study with the Department Chairman and Graduate Coordinator. This form will contain a listing of the courses which will make up his/her program. Any changes must have the approval of the Department Graduate Committee.

Thesis

Each student will be required to undertake a 6 semester-hour thesis. All students will defend their theses when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis, s/he will be required to submit a brief monthly report, showing progress of his/her thesis and approval by his/her advisor to the staff of the Department.

Courses of Study

10-501 Paper Industry Process Analysis **(3-0)3**

Prerequisite: Permission of Instructor

Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification, mechanical processing of fiber and sheet formation. Chemical Engineering Theory is applied to the analysis of these operations.

10-504 Process Calculations of Paper and Pulp Processes **(3-0)3**

Prerequisite: Permission of Instructor

Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

11-503,504 Advanced Converting Processes **(2-3)(2-3)6**

Prerequisite: Permission of Instructor

Specific converting processes. Analysis of coating processes; water and solvent based, extrusion and hot melts. Latest techniques used by the converting industry, involving mechanical and chemical operations. Engineering analysis of processes. Oral and written reports, plant visits, and laboratory assignments.

11-505 The Physics of Paper **(3-0)3**

Prerequisite: Permission of Instructor

Structures of fibers from a fundamental viewpoint and their effect on strength and other properties of sheets made of these fibers. Comparison of cellulosic fibers and synthetic fibers. Engineering properties of fibrous materials.

11-506 New Techniques in the Paper Industry **(3-0)3**

Prerequisite: Permission of Instructor

Lectures and discussions of new developments in engineering, design, and application of physical and chemical principles in the manufacture of paper products. Economic comparisons of new processes. Oral and written reports, plant visits, and laboratory assignments.

11-507 Fundamentals of Reprography **(3-0)3**

Prerequisite: Permission of Instructor

An in-depth study of replicating and imaging systems from carbon paper to xerography, to holography, covering theory and principles of operation, design and development of hardware and supplies, typical specifications and cursory economic evaluation of these systems. Because of the unique technical character of this new field, a review of copyright, patents and trade secrets is provided. The current state of the art is reviewed and the potential represented by recent developments in the field is examined.

11-508 Advanced Paper Systems Analysis **(3-0)3**

Prerequisite: Permission of Instructor

A study of the instrumentation and measurement systems used to monitor and control the processes of pulp and papermaking. Discussions consider the fundamental properties measured as well as the components in the process which interfere with the measurements.

11-512 Advanced Fiber Processing **(3-0)3**

Prerequisite: Permission of Instructor

A study of fiber properties as related to fiber processing. Treatment of various theories of fiber processing. Discussion of mechanical treatments of fibers on the wet and dry properties of papers made from these fibers.

11-651 Selected Topics in Paper Engineering **(3-0)3**

11-652 Selected Topics in Paper Engineering **(3-0)3**

Prerequisite: Permission of Instructor

Advanced topics in the various fields of paper engineering. Content may vary from year to year to reflect contemporary applications of paper engineering.

11-701 Graduate Research in Paper Engineering **(0-9)3**

11-702 Graduate Research in Paper Engineering **(0-9)3**

Prerequisite: Permission of Advisor

Every graduate student is required to write a thesis on original research work done under the supervision of a senior committee appointed by the Department Chairman.

DEPARTMENT OF CIVIL ENGINEERING

DEPARTMENT CHAIRPERSON: DONALD G. LEITCH,
Professor; B.S., Lehigh University; M.S., University of Colorado; P.E.

GRADUATE COORDINATOR: LOUIS C. TARTAGLIONE, *Associate Professor;* B.S., Manhattan College; M.S., University of Connecticut; P.E.

Faculty:

Frank P. Alberti, *Associate Professor;* B.S., Tufts University; M.S., Worcester Polytechnic Institute; M.S.M.E., Northeastern University; Ph.D., University of New Hampshire, P.E.
Susan Faraji, *Assistant Professor;* B.S., Arya-Mehr University of Technology; M.S., Northeastern University; Ph.D., University of Massachusetts.
Nathan H. Gartner, *Professor;* B.S., M.S., Sc.D., Technion-Israel Institute of Technology.
Rezene G. Medhani, *Assistant Professor;* B.S., University of Addis Ababa; M.S., Ph.D., University of Oklahoma.
William B. Moeller, *Professor;* B.S., Villanova University; M.S., Ph.D., University of Connecticut; P.E.
Charles R. Ott, *Professor;* B.S., M.S., Ph.D., University of Washington.
A. Mark Ratner, *Assistant Professor;* B.E., M.E., Stevens Institute of Technology; M.S., Cornell University; Ph.D., Stevens Institute of Technology, P.E.
Burton A. Segall, *Professor;* B.C.E., Polytechnic Institute of Brooklyn; M.S., M.P.H., University of North Carolina; Ph.D., New York University; P.E.
John J. Sewell, *Associate Professor,* B.S., C.E., Massachusetts Institute of Technology.

Master of Science in Engineering Degree Program

Graduate study in Civil Engineering is an intensive design and planning oriented program of instruction at an advanced technical level. The program includes curricula in the areas of geotechnical engineering, structural engineering, transportation engineering, water resources and environmental engineering.

The program permits students to construct, in consultation with their advisor, a plan of study which is suitably balanced and in accord with their own goals and career objectives. Instruction in the M.S.C.E. Program is planned for late afternoon and evening class meetings.

A special combined BSCE/MS Eng. five-year program is available to qualified undergraduate students at the University. Enrollment in this program usually takes place at the end of the junior year.

The objectives and philosophy of each of the curricula and the special requirements are outlined below.

General Requirements

Applicants who satisfy the Graduate School admission requirements will be assigned to a Graduate Faculty member who will act as their academic advisor. The M.S. Eng. degree requires the successful completion of 30 credit hours. This includes at least 24 hours in class and seminar work at the appropriate level, and at least six hours in preparation of a publishable thesis, or 27 credit hours of class-seminar work and at least three hours in preparation of a project report.

During the first semester an advisory committee will be established for each degree candidate and each candidate will file a plan of study acceptable to the committee. Students accepted on a provisional basis will follow the same procedure. After having enrolled for nine hours of instruction, the status of provisional students will be reviewed by the faculty who may then either admit them to matriculated status or refuse admission.

Those admitted to graduate study as non-degree students may reapply at a later date for matriculated status. However, no more than 9 credits of work completed while on non-degree student status will be used toward a degree. Faculty review of the petitioner's performance in all courses attempted will follow the same criteria as used for provisional status petitioners. If accepted, the student will thereupon file an acceptable plan of study as required of all degree candidates.

M.S. Eng. In Geotechnical Engineering

The master's degree program in geotechnical engineering will encompass soil mechanics theory and its application to practical engineering problems in the fields of foundation and soil engineering. The course work will emphasize the engineering properties of soil, how the properties are determined, and how they are used with soil mechanics theory in the solution of soil and foundation engineering problems.

Special Requirements

The student entering this program will be expected to have a B.S.C.E. degree or its equivalent, with at least one elementary course in soil mechanics and the usual civil engineering background in statics, strength of materials and fluid mechanics.

Core Courses

All students will be required to complete the following courses:

14-531 Advanced Soil Mechanics I
14-532 Advanced Soil Mechanics II
14-533 Advanced Foundation Engineering
14-534 Soil Dynamics
14-536 Soil Engineering

Elective Courses

The student is required to complete at least three courses in the following areas.

Structural Pavement Design
Soil Stabilization
Engineering Systems Analysis
Stochastic Concepts
Matrix Methods in Structural Analysis
Ground Water Hydrology
Advanced Strength of Materials

M.S. Eng. In Structural Engineering

The purpose of this area of study is to provide the student with advanced concepts and techniques which can be applied to the solution of complex structural engineering problems.

Special Requirements
A student seeking an M.S. Eng. in Structural Engineering must have a B.S. degree in engineering which includes senior level courses in analysis of statically indeterminate structures and in the design of steel and concrete structures. Students deficient in these areas must take these courses as prerequisites before they can take advanced courses.

Core Courses
All graduate programs in structural engineering will be developed to meet the needs of the individual; however, each student should take or be able to show proficiency in the following courses:

14-501 Engineering Mathematics I
14-504 Advanced Strength of Materials
14-551 Design of Steel Structures
or
14-552 Design of Reinforced Concrete Structures
14-555 Matrix Methods in Structural Analysis

Elective Courses
Additional courses taken from the Departments of Civil Engineering, Mechanical Engineering, Mathematics, Plastics Engineering, Economics, Management, etc, may be used to complete the student's program. All elective courses must be approved by the student's faculty advisor and/or advisory committee.

M.S. Eng. In Transportation Engineering

The program in Transportation Engineering offers courses encompassing planning, design and operations of multi-modal transportation facilities. It emphasizes the interdisciplinary nature of the subject, drawing on techniques from management, economics, operations research and environmental studies as a supplement to engineering concepts. It is designed to provide the student with advanced technical knowledge for addressing transportation problems in a variety of practical situations. Specialization in a certain area can be achieved through thesis and project work.

Special Requirements
Students desiring to enter the graduate program in Transportation Engineering should have an undergraduate engineering degree, or be otherwise prepared in mathematics, physical science and engineering science. Students lacking an engineering background may also be admitted, but may be required to take selected courses in engineering fundamentals before taking advanced courses.

Core Courses
A Graduate plan of study will be determined to meet the professional needs of each student; however, at a minimum, each student is expected to have completed or show proficiency in the following courses:

14-441 Traffic Engineering
14-540 Urban Transportation Planning
14-581 Engineering Systems Analysis
14-583 Stochastic Concepts

Elective Courses
14-543 Transportation Systems Analysis
14-545 Public Transit Planning and Design
14-547 Airport Planning and Design
14-549 Analysis of Traffic Flows
Elective courses from other appropriate disciplines such as engineering, management, and pure and applied science may be taken to form a coherent program in Transportation Engineering.

M.S. Eng. In Environmental Engineering and Water Resources

The program offers an opportunity to pursue a broad range of interests in the fields of environmental engineering and water resources. The course of study is designed to meet an individual student's interests and career goals. Programs consist of civil engineering courses in water and wastewater treatment, environmental chemistry, hydrology, hydraulics, and courses from allied disciplines in limnology, ecology, microbiology, environmental law, and organic and radiological chemistry.

Special Requirements
Degree program students in environmental engineering and water resources must have a B.S. degree in engineering. Undergraduate course deficiencies in selected areas of study must be completed before taking advanced courses.

Core Courses
All students are required to complete:
14-567 Environmental Chemistry I.

Elective Courses
Individual programs consist of a complement of elective courses from within Civil Engineering, the College of Engineering, the College of Pure and Applied Sciences and other areas within the University.

The Five-Year BS/MS Eng. Program

The program offers qualified undergraduate students a course of study leading to a Masters Degree in Civil Engineering at the end of five years of study. Students benefit from the efficiency of a continuous, coordinated sequence of subjects which permits reduced credit hour requirements.

General Requirements - Five-Year Program

A minimum grade point average of 3.0 is required for admission into the five-year Civil Engineering graduate program; however, a student with an average between 2.75 to 3.0 may be admitted provisionally with departmen-

tal approval. The grades of the student's first five semesters will be used to determine the grade point average.

Applicants who satisfy the Graduate School and Civil Engineering Department admission requirements for the five-year program will be assigned a Graduate Faculty member who will act as their program advisor. The first year M.S. Eng. degree requires the successful completion of a minimum of 30 credit hours. These 30 hours include at least 24 hours in class and seminar study of which at least 18 hours must be at the 500 level or higher. Also, at least 6 credit hours must be completed in preparation of a publishable thesis. Courses at the 400 level are designed for seniors, but under certain circumstances may be taken by graduate students for graduate credit. The student must file a Special Petition form obtainable from the Graduate School, at the time of registration for the 400 level courses.

Special Requirements

A student seeking a five-year M.S. Eng. degree may undertake a general Civil Engineering program or may choose an area of specialized study. These areas include: Environmental Engineering, Water Resources, Geotechnical Engineering, Structural Engineering and Transportation Engineering. The student who specializes must take at least four electives in the area of specialization or from an associated area as approved by his/her program advisor.

Core Curriculum Requirements

All students are required to complete the following seven core curriculum courses. It is recommended that they take at least two core courses per term during their 4th and 5th years. After considering the student's overall plan of study, the sequencing of the core curriculum courses will be determined by the student and the advisor.

Fall Term		*Credits*
14-431	Foundations and Soils Engineering	3
14-452	Steel Design	3
14-460	Water Resources Engineering	3
16-211	Fundamentals of Electricity	3
Spring Term		
14-470	Civil Engineering Economics	3
22-347	Elements of Thermodynamics & Heat Transfer	3
14-461	Water Resources Designs	3

TYPICAL PLAN OF STUDY
Fourth Year

Fall Semester			*Spring Semester*		
2	Core Curriculum Courses	6	2	Core Curriculum Courses	4 or 6
	Area I or II Elective	3		Area I or II Elective	3
2	Civil Engineering Electives	6	2	Civil Engineering Electives	6
		15 hours			15 hours

Fifth Year

Fall Semester		*Spring Semester*	
2 Core Curriculum Courses	6	2 Core Curriculum Courses	4 or 6
2 Civil Engineering Electives	6	2 Civil Engineering Electives	6
Thesis	3	Thesis	3
	15 hours		15 hours

At least six of the required eight Civil Engineering electives must be at the 500 level or above. These courses may be taken in Civil Engineering or in an associated area approved by the student's advisor.

The 30 hours that are required for the master's degree are considered to be the following:

8 Civil Engineering Electives	24 hours
1 Thesis	6 hours
	30 hours

Under exceptional circumstances, students wishing to terminate their plan of study before the completion of the 5th year must at least successfully complete the seven core curriculum course requirements, the two Area I or II Electives and the two Civil Engineering Electives which are part of this program, to obtain a BSCE.

Courses of Study

14-501 Engineering Mathematics I (3-0)3
Series solutions to second order differential equations, Bessel and Legendre functions, Vector analysis, Differentiation formulas, Line and Surface integrals, The Divergence Theorem.

14-504 Advanced Strength of Materials (3-0)3
Stress and strain at a point, curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections, theories of failure, introduction to the theory of elasticity.

14-505 Introduction to the Theory of Elasticity (3-0)3
Analysis of Cartesian tensors using indicial notation. Stress and strain concepts. Exact solutions to equations governing stress and displacement of elastic solids.

14-506 Computational Methods in Engineering (3-0)3
Difference Operations. Solutions of Differential Equations by Finite Differences. Matrices and Related topics. Solution of ordinary differential equations, functional representation, solution of algebraic and transcendental equations.

14-531 Advanced Soil Mechanics I (3-0)3
and
14-532 Advanced Soil Mechanics II (3-0)3
Basic theories of soil mechanics and their application under practical conditions. Basic strength principals and stress-strain behavior of clay, cohesionless and mixed types of soil.

14-533 Advanced Foundation Engineering (3-0)3
Design and analysis of shallow and deep foundations for various types of soil profiles will be studied. Foundations contiguous to existing structures will be investigated.

14-534 Soil Dynamics (3-0)3
Design of dynamically loaded foundations including the necessary elements of dynamics. Only an elementary dynamics course will be assumed as background. The principles to be developed will apply to dynamic loading due to machinery, earthquakes, or blasting.

14-536 Soil Engineering (3-0)3
The study of soil as an engineering material, and its use in earth dams, road embankments, and compacted fills. Stability of natural slopes wil be studied.

14-537 Structural Pavement Design (3-0)3
Analysis of pavement loads and stresses, pavement material characterization, design of flexible and rigid highway and airport pavements, pavement evaluation and rehabilitation.

14-538 Soil Stabilization (3-0)3
Granulometry and colloid chemistry as related to soil plasticity classification, strength and mix design. Use and evaluation criteria for suitability of chemical stabilization (cement, lime, fly ash, etc.) and bituminous stabilization.

14-540 Urban Transportation Planning (3-0)3
Basic principles of urban transportation planning. Characteristics of urban travel; characteristics of urban transportation systems. Data collection for transportation planning. Analysis of urban travel demand; analysis of transportation system performance. Transportation project evaluation; project implementation.

14-543 Transportation Systems Analysis (3-0)3
Demand, supply and equilibrium in multimodal transportation systems. Analysis of transportation demand, transportation technologies and performance functions. Consequences of transportation decisions; searching for optimal design strategies.

14-545 Public Transit Planning and Design (3-0)3
Role of public transit; transit system design and operating characteristics including accessibility, speed, capacity, headway and terminal layout and operation; developments in transit technology.

14-547 Airport Planning and Design (3-0)3
Planning, locating and designing airport facilities; airport financing; air traffic control; aircraft characteristics; estimation of aeronautical demand; site selection and environmental effects; planning and design of terminals and heliports.

14-549 Analysis of Traffic Flows (3-0)3
Microscopic and macroscopic models of traffic flows on transportation facilities. Levels of service and quality of service as influenced by physical design aspects and operational control measures.

14-550 Advanced Structural Analysis (3-0)3
Beams on elastic foundation. Significant attention to linear and non-linear concepts of buckling stability. Introduction to plates and shells. Finite Differences, Newmark numerical methods.

14-551 Design of Steel Structures (3-0)3
Elastic and plastic design of structural steel systems, residual stresses, local buckling, beam-columns, torsion and biaxial bending, composite steel-concrete members, load and resistance factor design.

14-552 Design of Reinforced Concrete Structures (3-0)3
Review of USD and WSD methods for flexure and shear, anchorage, torsion, and deep beams, slender columns and beam-columns, deflections, slabs and walls.

14-553 Timber Structures **(3-0)3**
Design of timber members in tension, compression and bending; design of connections, laminated wood trusses and frames.

14-554 Prestressed Concrete Design **(3-0)3**
An introductory course in the analysis and design of prestressed concrete structures. ACI/PCI Code applications.

14-555 Matrix Methods in Structural Analysis **(3-0)3**
Matrix analysis of framed structures, flexibility and stiffness methods. Computer techniques.

14-557 Structural Dynamics **(3-0)3**
Analysis of structures subjected to dynamic loads; free, forced and damped vibrations with one or multi-degrees of freedom. Dynamic response of beams, framed structures, tall buildings and bridges, response to earthquake loadings.

14-559 Advanced Projects in Structural Engineering **(3-0)3**
Studies of topics of special interest and need of the student in structural analysis and/or design.

14-561 Physical Chemical Treatment Processes **(3-0)3**
Theories of physical chemical treatment processes and the laboratory (or pilot plant) techniques necessary to obtain design. Treatment processes for natural waters, domestic wastes, and industrial wastes. Development of design methods and the relationship of these processes to environmental quality.

14-562 Groundwater Hydrology **(3-0)3**
Description and analysis of the occurence and movement of groundwaters. Evaluation of aquifiers, aquifer development, and sampling. Examination of field problems such as pollution and salt water intrusion.

14-563 Hydraulics of Open Channels **(3-0)3**
Problems of varied or non-uniform flow in open channels, surface profile determinations, hydraulics of reservoirs and treatment works under unsteady flow conditions. Primary interest on applications and typical cases.

14-564 Hydrology **(3-0)3**
Basic hydrologic concepts, generation of input for design by processing of time series, correlations and frequency distribution.

14-565 Industrial Waste Treatment Processes **(3-0)3**
An introduction to the unit operations most commonly encountered in industrial waste treatment. Specific industrial applications will be stressed after an understanding of each unit operation has been developed.

14-566 Biological Waste Treatment Processes **(3-0)3**
Selection and design of aerobic and anaerobic biological waste treatment processes. Techniques for generating design data and prediction of process efficiency. Laboratory exercises including bench scale studies.

14-567 Environmental Chemistry I **(3-0)3**
The chemistry of natural waters and of water and wastewater treatment. Dilute aqueous solution chemistry of acid-base reactions and complex formation. Emphasizes chemical equilibrium. Foundation for environmental studies.

14-568 Environmental Chemistry Applications **(3-0)**
The application of natural and polluted water chemistry. Lecture and laboratory projects develop analytical techniques and a knowledge of water treatment technology.

14-569 Advanced Projects in Water Resources (3-0)3
Studies of topics of special interest and need of students in environmental engineering and water resources design.

14-570 Small and Alternative Waste Water Treatment (3-0)3
A design oriented course covering subsurface disposal, surface systems disposal, nonconventional collection systems and planning approaches.

14-581 Engineering Systems Analysis (3-0)3
Methods of operations research, management science and economic analysis used in the design, planning and managing of engineering systems.

14-583 Stochastic Concepts (3-0)3
Effects of uncertainty in engineering design and decision making. Emphasis on practical applications of mathematical principles and tools of probability and statistics to problems in civil engineering.

14-651 Special Topics in Civil Engineering (3-0)3
Course content and credits to be arranged with instructor who agrees to direct the student.

PROGRAM IN ENVIRONMENTAL STUDIES (CIVIL ENGINEERING)

GRADUATE COORDINATOR: BURTON A. SEGALL, *Professor of Civil Engineering;* B.C.E., Polytechnic Institute of Brooklyn; M.S., M.P.H., University of North Carolina; Ph.D., New York University.

Faculty Associated with the Environmental Studies Program:

Eugene F. Barry, *Professor of Chemistry;* B.S., Villanova University; Ph.D., University of Rhode Island.
John I. Bruce, *Professor of Biological Sciences;* B.S., Morgan State College; M.S., Ph.D., Howard University.
Alfred A. Donatelli, *Assistant Professor of Chemical Engineering;* B.S., M.S., Lowell Technological Institute; Ph.D., Lehigh University.
Nelson G. Eby, *Associate Professor of Earth Science;* A.B., M.S., Lehigh University; Ph.D., Boston University.
Jesse Y. Harris, *Professor of Physics/Radiological Sciences;* B.S., M.S., Ph.D., Rutgers-The State University.
Charles J. Higgins, *Professor of Chemical Engineering;* B.S., Lowell Technological Institute.
Ethel Kamien, *Professor Biological Sciences;* B.A., Brooklyn College; M.S., Ph.D., University of Wisconsin.
John C. Mallett, *Associate Professor of Biological Sciences;* B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.
William B. Moeller, *Professor of Civil Engineering;* B.S., Villanova University; M.S., Ph.D., University of Connecticut.
Arnold L. O'Brien, *Associate Professor of Earth Sciences;* Ph.D., Boston University; A.B., M.S., Syracuse.
Charles R. Ott, *Professor of Civil Engineering;* B.S., M.S., Ph.D., University of Washington.
Karl J. Sladek, *Professor of Chemical Engineering;* B.S., M.S., Sc.D., Massachusetts Institute of Technology.

Master Of Science in Engineering Degree Program

This interdisciplinary program leads to a Master of Science in Engineering Degree in Environmental Studies. The program of study consists of course

work in environmental law, air resources management, water resources, waste management and at least five area-specific technical electives. Either laboratory or investigative research is required.

The Environmental Studies Program meets the needs of students planning environmental management careers with Federal agencies, state and local governments, consulting firms or industry.

Enrollment in the program is open to individuals with a baccalaureate degree in engineering, biology or a physical science. Others may be admitted provisionally with the approval of the Program Coordinator. Course prerequisite deficiencies can be made up while in the program.

Degree Requirements

Frequently, students entering the program are required to take a number of undergraduate courses to develop analytical skills and to prepare for advanced level course work. Undergraduate courses may include calculus, statistics, biochemistry, organic chemistry, computer programming or courses designed to develop problem-solving techniques. Course requirements are determined by the Program Coordinator.

Requirements for graduation include:

A minimum of 33 credits in required core courses, electives, and thesis.

Required Courses:

18-510 Water Resources Management
18-522 Municipal, Industrial & Hazardous Waste Management
18-523 Air Resources Management
18-527 Environmental Law
18.701 Graduate Research in Environmental Studies

Technical Electives

Example programs of study, for students with undergraduate preparation in biology, chemistry and earth sciences, are shown below. Technical elective selection by a student and the Program Coordinator, is based upon student's undergraduate discipline, preparation and individual interest and need. Technical electives are usually chosen from graduate level courses offered by the Colleges of Engineering and Pure and Applied Science. Selections from the Colleges of Management Science, Health Professions and Liberal Arts may also be included.

Thesis

Students enrolled in the program are required to complete a six-semester hour thesis, consisting of laboratory research or scholarly investigation. Students choose their principal advisor, a member of the University of Lowell Faculty and two associate advisors, at least one of whom must be a member of the faculty. Committee selection and the thesis topic are subject to the approval of the Program Coordinator.

Courses available in areas of concentration

Chemistry Focus

14-561	Physical Chemical Treatment Processes
14-567	Environmental Chemistry I
18-525	Epidemiology for Environmental Studies
18-553	Special Topics in Environmental Studies
18-568	Instrumental Methods of Analyses
84-526	Theory and Applications of Chromatography
84-568	Structural Analyses
84-585/586	Nuclear and Radiochemistry

Biological Sciences Focus

14-565	Industrial Waste Treatment Processes
14-567	Environmental Chemistry I
18-525	Epidemiology for Environmental Studies
18-553	Special Topics in Environmental Studies
81-506	Physiological Ecology
81-508	Physiological Ecology Lab
81-510	Limnology
81-512	Limnology Lab
81-522	Plant Physiology
81-524	Plant Physiology Lab
81-529	Laboratory Instrumentation

Earth Science Focus

14-535	Engineering Geology
14-536	Soil Engineering
14-562	Groundwater Hydrology
18-503	Oceanography
18-514	Hydrogeology
18-525	Epidemiology for Environmental Studies
18-526	Glacial and Pleistocene Geology
18-531	Regional Geology
18-552	Geochemestry
18-553	Special Topics in Environmental Studies
18-554	Economic Geology

Courses of Study

18-503 Oceanography **(3-0)3**
A survey of the geologic, chemical, physical and biological aspects of the oceans. Topics include a study of the topography, structure, and origin of ocean basins and their margins, marine sedimentation, chemistry and circulation of ocean waters, and biological environments. Special Project required. Not open to students who have taken 89-203 or equivalent.

18-510 Water Resources Management **(3-0)3**
Concepts and methodologies of hydrology, constraints and objectives of water resources management, and the interrelationship between hydrologic and managerial components of water resource issues. Case studies are reviewed and discussed.

18-514 Hydrogeology (3-0)3
A study of the distribution and movement of water on the earth's surface with emphasis on the geologic effects. Topics include application of statistics to streams, ground-water flow nets, well hydraulics. Special Progect required. Not open to students who have taken 89-314 or equivalent.

18-520 Environmental Impact Statements (3-0)3
Methodology for preparing environmental impact statements. Required information and methods of writing the statements for both federal and state agencies. Current and future review systems are discussed.

18-522 Municipal, Industrial and Hazardous Waste Management (3-0)3
Generation, treatment and disposal of municipal solid wastes, industrial solid and waste-treatment process sludges and solid and liquid hazardous wastes. Topics include, physical, chemical and biological characterization of wastes, regulations governing their disposal, and treatment, recycling and disposal technology.

18-523 Air Resources Management (3-0)3
Sources and reaction chemistry of atmospheric pollutants. Topics include process and ambient air monitoring, methods of analysis, air pollution regulations, contaminant removal technology and atmospheric dispersion processes, and adverse effects of atmospheric pollutants.

18-525 Epidemiology for Environmental Studies (3-0)3
The study of the distribution and determinants of disease in human population and how these diseases are disseminated by environmental changes. The methods used in conducting epidemiological investigations including descriptive analytical and experimental studies, patient care and cohort studies.

18-526 Glacial and Pleistogene Geology (3-0)3
A survey and interpretation of the erosional and depositional effects of glaciation with emphasis on the New England area. Topics include glaciology, glacial geology, and Pleistocene stratigraphy. Special Project required. Not open to students who have taken 89-326 or equivalent.

18-527 Environmental Laws (3-0)3
The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protection Agency and the Occupational Safety and Health Acts. Local laws and ordinances are discussed where pertinent.

18-530 Problems in Environmental Health (3-0)3
Relationships between environmental health and man's activities. The impact of science and technological advances on the environmental health of a community. Dangers arising from air pollution, contamination of water supplies, sewage and industrial wastes, radioactive substances, insecticides and herbicides, contamination of food by chemical and biological agents, occupational hazards, and solid waste disposal, and its deterioration of recreation waters.

18-531 Regional Geology (3-0)3
A survey of the stratigraphy, geologic structure, and physiography of various areas of the world with emphasis on North America. Discussions on the origin of various geologic provinces and the development of a model for global tectonics. Special Project required. Not open to students who have taken 89-431 or equivalent.

18-552 Geochemistry (3-0)3
Application of chemical principles to geologic problems. Topics include crystal chemistry, phase equilibria, stable isotopes and age dating, oxidation-reduction and pH of natural environments, abundance and distribution of elements in the earth, origin and evolution of igneous, metamorphic, and sedimentary rocks. Special Project required. Not open to students who have taken 89-452 or equivalent.

18-553 Special Topics in Environmental Studies (3-0)3
Special environmental projects undertaken by students. Course contents and credits are arranged with an instructor associated with the Environmental Studies program.

18-554 Economic Geology (3-0)3
A study of the processes which lead to the formation of nonmetallic and metallic mineral deposits. Topics will include the origin of fossil fuels, sedimentary ore deposits, and ore deposits formed by igneous and metamorphic processes. Special Project required. Not open to students who have taken 89-454 or equivalent.

18-568 Instrumental Methods of Analysis (0-3)1
Instrumental methods applied to the analysis of potable, surface and ground waters and industrial and municipal wastewaters. Emphasis is placed upon instrumental techniques including atomic absorption spectroscopy, gas chromatography and potentiometric methods.

DEPARTMENT OF ELECTRICAL ENGINEERING

DEPARTMENT CHAIRPERSON: RONALD D. BRUNELLE, *Associate Professor;* B.S., M.S., Lowell Technological Institute; P.E.

GRADUATE COORDINATOR: DONN A. CLARK, *Associate Professor;* B.S., Pennsylvania State University; M.S., Northeastern University. P.E.

Faculty:

Francesco L. Bacchialoni, *Associate Professor;* Dott., Ing., University of Genova.
Michael J. Barrett, *Assistant Professor;* B.S., Northeastern University; M.S., University of California at Berkeley; Ph.D., University of California at Santa Barbara.
Roger H. Baumann, *Professor;* S.B., S.M., Massachusetts Institute of Technology; Sc.D., University of Paris.
Peter Burger, *Professor;* B.S., Vanderbilt University; M.S., Ph.D., Stanford University.
George P. Cheney, *Associate Professor;* B.S., M.S., Lowell Technological Institute.
Robert J. Dirkman, *Associate Professor;* B.S., Tufts University; S.M., Massachusetts Institute of Technology.
F. Ross Holmstrom, *Professor;* B.S., University of Washington; M.S., Ph.D., Stanford University.
Charles W. Jim, *Assistant Professor;* B.S., M.S., Ph.D., University of Colorado.
Dikshitulu Kalluri, *Associate Professor;* B.E., Andhra University; M.S., University of Wisconsin; D.I.I.Sc., Indian Institute of Science; Ph.D., University of Kansas.
Alexander Khazan, *Professor;* M.S., Moscow University; Ph.D., Moscow Engineering Institute.
Venkatarama Krishnan, *Professor;* B.S., Banaras Hindu University; B.S., Madras University; M.S., Princeton University; Ph.D., University of Pennsylvania.
Walter S. Kuklinski, *Associate Professor;* B.S., Lowell Technological Institute; M.S., Ph.D., University of Rhode Island.
E. Russell Laste, Jr., *Professor;* B.S., M.S., Northeastern University; Ph.D., Worcester Polytechnic Institute.
Shreedhar G. Lele, *Associate Professor;* B.S., M.S., Banaras Hindu University; M.S. University of Michigan; Ph.D., University of Michigan.
J. Robert A Lemieux, *Associate Professor;* B.S., M.S., Lowell Technological Institute.
John P. Leonard, *Associate Professor;* B.S., Lowell Technological Institute; M.S., Northeastern University.
Harry E. Moses, *Associate Professor;* B.S., M.S., University of Michigan; Ph.D., Columbia University.

Paul J. Murphy, *Associate Professor;* S.B., S.M., Massachusetts Institute of Technology; P.E.
Robert E. Parkin, *Associate Professor;* B.S., University of London; D.I.C, Ph.D., Imperial College, University of London.
Martin A. Patt, *Associate Professor;* B.S., Northeastern University; S.M., Massachusetts Institute of Technology.
James E. Powers, *Professor;* B.S., M.S., Lowell Technological Institute.
Kanti Prasad, *Associate Professor;* B.S., University of Roorkee; B.S., Agra University; Ph.D., University of South Carolina.
Craig G. Prohazka, *Assistant Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Massachusetts Institute of Technology; Ph.D., University of Massachusetts.
Tenneti C. Rao, *Assistant Professor;* B.S., Andhra University; B.S., M.E., Ph.D., Indian Institute of Science, Bangalore.
Bodo W. Reinisch, *Professor;* M.S., University of Frieburg; Ph.D., University of Lowell.
H. James Rome, *Associate Professor;* B.S., M.S., University of Michigan; Ph.D., University of Pennsylvania.
Gary S. Sales, *Associate Professor;* B.S., Brooklyn College; M.S., Ph.D., Pennsylvania State University.
Stephen J. Spurk, *Associate Professor;* B.S., Merrimack College; M.S., University of New Hampshire.
Anh Tran, *Assistant Professor;* B.S., National Taiwan University; M.S., Ph./D., University of Rhode Island.
David P. Wade, *Associate Professor;* B.S., Lowell Technological Institute; M.S., Northeastern University.
Fahd G. Wakim, *Associate Professor;* B.S., American University of Beirut; M.A., Ph.D., University of Texas.
David A. Wunsch, *Associate Professor;* B.E.E., Cornell University; S.M., Ph.D., Harvard University.

MASTER OF SCIENCE IN ENGINEERING DEGREE PROGRAM

The Electrical Engineering Department offers degrees at the master's level in Electrical Engineering, Computer Engineering and Systems Engineering. In addition, a five year B.S./M.S. program is offered in any one of the three programs. A student can elect a thesis or non-thesis option. A master's degree will be awarded upon satisfactory completion of 30 credit hours of study under the thesis option, of which the thesis provides 6 credit-hours; thirty-three credit hours of study is needed for the non-thesis option, with the 3 credit hour seminar course 16.700, being required plus 12 credit hours of study in a particular concentration.

B.S./M.S. ENG. PROGRAM

The five year B.S./M.S. Eng. program is an option available to undergraduates with a cumulative grade point average in excess of 3.0 at the end of their sophomore year who have identified a specific academic objective; the academic advisor must approve the proposed course of study. The cumulative grade point average must be maintained at 3.0 or above throughout the program. The student enrolls in the program during the spring semester of the junior year, but can withdraw from the program at any time without affecting bachelor degree eligibility.

ENTRANCE AND OTHER REQUIREMENTS

To be eligible for admission to the master's degree program in Electrical Engineering, the applicant must have received a bachelor's degree or

equivalent in electrical engineering with an acceptable quality of undergraduate work from a recognized college or university. To be eligible for admission to the master's degree programs in Computer Engineering and Systems Engineering the applicant must have received a bachelor's degree or equivalent in a physical science (including computer science or mathematics) with an acceptable quality of undergraduate work from a recognized college or university. The following undergraduate courses are considered prerequisites for the Computer Engineering program: 6 credits calculus; 6 credits advanced mathematics; 9 credits circuit theory, electronics and associated laboratory; 3 credits logic design and laboratory; 3 credits FORTRAN; and 3 credits absolute and symbolic programming. The GRE aptitude examinations are required. Both the quality and quantity of previous training are used to assess suitability for matriculation.

If the graduate coordinator ascertains that a candidate has fulfilled most but not all of the requirements for admission, the graduate coordinator may admit the student into the master's program on a provisional basis. When all the requirements are met, a provisional student must present an academic petition for change in status to that of a matriculated student. Such provisional students are permitted, upon matricualtion, to apply up to 12 credit hours of acceptable course work taken under non-matriculated status for credit towards the master's degree. This same 12 credit-hour rule applies to students entering the master's degree program for the first time.

Satisfactory student performance is evidenced in part by grades of B or higher. A matriculated student receiving 6 credit-hours of the grades BC and/or C will be automatically reclassified as a provisional student. The graduate coordinator will inform the Graduate Affairs Committee of all students with more than 6 credit-hours of the grades BC and/or C, and the Graduate School retention policy will apply.

No more than 6 credit-hours of senior level undergraduate courses in electrical engineering and/or applied physics and/or mathematics may be used to fulfill the course requirements for the master's degree programs. Such courses must be approved by the graduate coordinator and cannot be prerequisites for the student's program of study.

EVENING COURSES (CONTINUING EDUCATION)

Admission requirements for the part-time evening program leading to the degree of Master of Science in Engineering are the same as for the full-time program, but students may progress according to their abilities and the time available to them, provided they complete requirements within the five-year period. Courses are offered through the Division of Continuing Education and are interchangable with the corresponding day school courses. The thesis option is not available through the Continuing Education program. An evening student wishing to enroll in the thesis option must contact the graduate coordinator, find a faculty advisor, and enroll in the day school thesis course.

Dual Enrollment in Day and Evening Courses

Although the department does not lay down a firm residency policy for the Master's degree, it is expected that the student will become acquainted with

professionals in the field of engineering. This exposure can be obtained by either full-time day school enrollment for a minimum of 21 credit-hours but not less than 9 credit-hours per semester (i.e., 9-9-5 minimum) or by full-time employment in a local electronic or related industry.

With respect to the minimum course load required for teaching and research assistantship appointments, only the day load will be counted. Special written permission must be received from the student's advisor and the Graduate Affairs Committee of the department before a day student will be allowed dual (concurrent day and Continuing Education) registration. Such permission will be allowed only in extenuating circumstances. There is no impediment for Continuing Education students taking day courses.

Academic Advisor

Each graduate student admitted into the Electrical Engineering Department will be assigned an academic advisor who will assist him/her in the selection of courses and who will develop with the student a program which will meet his/her needs and the requirements for the desired degree.

Course Requirements

The master's degree in Electrical Engineering requires a minimum of 33 credit-hours of graduate study; 30 if the thesis option is followed. The four required core courses which are required for each degree program are:

ELECTRICAL ENGINEERING:

16.509 Linear Systems Analysis
16.513 Modern Control Theory
16.584 Probability and Random Processes, and
16.700 Seminar, or 16.730 Electrical Engineering Thesis

COMPUTER ENGINEERING:

16.520 Applied Numerical Methods
16.563 System Programming
16.574 Introductory Digital System, and
16.700 Seminar, or 16.731 Computer Engineering Thesis

SYSTEMS ENGINEERING:

16.509 Linear Systems Analysis
16.513 Modern Control Theory
16.584 Probability and Random Variables, and
16.700 Seminar, or 16.732 Systems Engineering Thesis

A non-thesis student must elect a concentration in order to obtain a broader and deeper understanding of a particular area. A concentration requires the student to take four courses in a specific area as well as four required courses. The specified concentrations and courses within the concentration are as follows:

Electrical Engineering Concentrations: -

Control Systems	16.510 16.519 16.613 16.614

Computer Hardware	16.675	16.574	16.674	16.676
Computer Software	16.522	16.524	16.563	16.564
Information and Communications	16.543	16.545	16.685	16.548
Microwave Circuits and Systems	16.604	16.506	16.507	16.533
Semiconductors and Microelectronics	16.502	16.503	16.602	16.603

Computer Engineering Concentrations: -

Software	16.522	16.663	16.524	16.564
Firmware	16.525	16.561	16.562	16.564
Hardware	16.561	16.675	16.674	16.676

Because of the wide range of topical coverage in Systems Engineering and because of the interdisciplinary nature of the Systems Engineering program, no specific concentrations are delineated. A non-thesis Systems Engineering student can design a concentration with approval and cooperation of the graduate coordinator according to his or her interests.

B.S./M.S. Eng. PROGRAM OF STUDY

The following courses of study are required for undergraduates admitted to the B.S./M.S. Eng. program. A technical elective should be taken in the Spring semester of the junior year in place of a humanistic-social elective. A proposal must be ready for review at the start of the Fall term of the graduate year. A suggested course of study for thesis students for their senior and graduate years is:

Senior Year

Fall Semester:		*Spring Semester:*	
H/S Elective	3	H/S Elective	3
16.461	3	H/S Elective	3
22.347	3	16.413	3
Grad Course #1	3	Grad Course #3	3
Grad Course #2	3	Grad Course #4	3

Graduate Year (thesis option)

Fall Semester:		*Spring Semester:*	
Grad Course #5	3	Grad Course #7	3
Grad Course #6	3	Grad Course #8	3
Thesis	3	Thesis	3
Tech Elective	3	Tech Elective	3

Graduate Year (non-thesis option)

Fall Semester:		*Spring Semester:*	
Grad Course #5	3	Grad Course #8	3
Grad Course #6	3	Grad Course #9	3
Grad Course #7	3	Grad Course #10	3
Grad Seminar	3	Tech Elective	3
Tech Elective	3		

An advantage of enrolling in the combined B.S./M.S. Eng. program is that two graduate courses are substituted for the two free electives taken in the senior year. These two graduate courses are credited towards the master's degree, thus reducing the total course load for B.S./M.S. students by 6 credit-hours. The courses of study followed during the junior and senior years must have the approval of the student's academic advisor and must satisfy all of the requirements for the B.S. degree. The graduate coordinator will ensure that the requirements for the M.S. degree are fulfilled by approving the courses of graduate study.

DOCTOR OF ENGINEERING DEGREE PROGRAM

The goal of the Doctor of Engineering Program is to develop decision-making engineers with sound theoretical and technical knowledge who are design and development-oriented and also have a firm background in engineering management. The doctoral degree requires 85-90 semester hours of study beyond the bachelor of science degree. A typical program is composed as follows:

Engineering Subject Courses	0 credits
Internship/Dissertation	30 credits
Engineering Management	15 credits

The Engineering Management program is administered at the College level and is described under the heading College of Engineering, Doctor of Engineering Program Interdepartmental Curriculum.

Admission Requirements

Applicants must submit official transcripts of their undergraduate courses indicating the award of a bachelor of science degree in Electrical Engineering from an accredited college or university. Students with an M.S. degree should also submit their official transcripts for that degree. Up to 24 credits in engineering subject courses are transferrable toward the doctoral program upon approval by the departmental Doctor of Engineering committee. In addition all students must submit an official score report for the Graduate Record Examination (general examination).

Internship and Dissertation

Each student is required to complete an internship of at least one year's duration in either industry, government, or the University. The purpose of the internship is to place the student in a realistic engineering setting in which he or she will function as a responsible engineer and carry out the work required for the dissertation. During the internship, the student will maintain close contact with the academic advisor. A written thesis must be submitted, and the student is required to make an oral defense of the dissertation.

Language Requirements
The student must demonstrate satisfactory reading ability (level two) in one foreign language (German, Russian, French or Spanish) which is not the student's native tongue. The language requirement may be satisfied by the following:

a) Passing an examination given by the Graduate Committee of the Electrical Engineering Department.
b) A one-year course with a grade of B or better beyond the first year. Option b) satisfies 6 credit requirements for the Engineering Management program.

Other Requirements
One year of full-time residency is required of all students in the program. To successfully complete the program, a student must achieve a cumulative grade point average of 3.25 in all course work.

Program Plan
Each student entering the program must develop a study plan in consultation with his/her Advisory Committee. During the first year, the student entering with a B.S. degree will take 24 credit hours of engineering courses in preparation for the qualifying exam which should be passed at the end of the first year of study. Students with an M.S. degree may take the qualifying exam at the first possible date. The qualifying exam will be administered twice a year, in the first week of February and the first week of June.

During the second year, the student continues the required course work and formulates a topic for the dissertation. The final period is devoted to advanced courses and to dissertation work.

Examination
The Electrical Engineering Department will administer a written qualifying exam on basic undergraduate and graduate engineering topics:

a) Electromagnetics
b) Linear Systems
c) Digital Systems
d) Engineering Mathematics and Computer Programming.

The student must have completed at least 24 credit hours of graduate courses with a 3.0 grade point average or better before s/he can take the exam. A student has two chances to pass the exam with a mark of pass or fail given for each examination.

Having passed the qualifying exam the student may submit his/her thesis proposal and defend it before the Doctoral Committee. Upon approval, the student will be reported to the College Doctoral Committee and the Dean of the Graduate School for placement on the list of candidates for the Doctor of Engineering Degree. Admission to the candidacy status does not guarantee the obtaining of the degree.

COURSE REQUIREMENTS

A. Basic Courses

As a basis for the qualifying exam, the following courses are recommended. Courses marked with R are required unless the student can give proof of competency or knowlege in that area. Graduate courses not listed above may be substituted for non-required courses with the approval of the Advisory Committee.

16.507	Electromagnetics I	R
16.509	Linear Systems Analysis	R
16.584	Probability and Random Processes	R
16.574	Introduction to Digital System Design	R
16.520	Applied Numerical Methods, or	
92.523	Linear Algebra, or	R
95.513	Classical Mechanics	
16.607	Electromagnetics II	
95.505	Mathematical Physics I	

B. Concentration

After passing the qualifying exam, the student will select one of the four available Concentrations of the D.E. program: Electromagnetics, Systems, Computers, or Solid State Devices.

Courses Recommended for the Electromagnetics Concentration:

16.506	Antenna Theory and Design	
16.520	Applied Numerical Methods	
16.532	Computational Electromagnetics I	R
16.533	Microwave Engineering	
16.534	Microwave Laboratory	
16.571	Radar Systems	
16.582	Radio Frequency Communications Systems Design	
16.583	Wave Propagation in Plasmas	
95.505	Mathematical Physics I	
95.506	Mathematical Physics II	
16.604	Microwave Devices	
16.607	Electromagnetics II	R
16.609	Inverse Scattering and Source Theory	
16.608	Scattering and Diffraction of EM Waves	
16.700	Seminar	

Courses Recommended for the Systems Concentration:

16.520	Applied Numerical Methods	R
16.525	Simulation Techniques	
15.543	Theory of Communication	
16.545	Coding Theory	
16.613	Non-Linear Control Systems	
16.614	Optimal Control Systems	

16.620 Robotics
16.676 Digital Systems Design Laboratory
16.687 Stochastic Estimation Theory and Applications
16.685 Statistical Communication Theory R
16.700 Seminar

Courses Recommended for Computer Concentration:
16.520 Applied Numerical Methods R
16.522 Data Structures
16.524 Programming Languages
16.525 Simulation Techniques
16.543 Theory of Communication
16.545 Coding Theory
16.548 Information Theory
16.561 Computer Organization and Design
16.562 Microprogramming
16.563 System Programming R
16.564 Operating Systems
16.574 Introduction to Digital System Design R
16.584 Probability and Random Processes
16.661 Computer/Local Area Networking
16.663 Compiler Structures
16.674 Digital Subsystem Design
16.675 Advanced Digital Devices
16.676 Digital Systems Design Laboratory
16.685 Statistical Communication Theory
16.700 Seminar

Courses Recommended for the Semiconductors and Microelectronics Concentration:
16.502 Introduction to VLSI Design R
16.503 Solid State Physical Electronics I R
16.602 Advanced VLSI Design
16.603 Solid State Physical Electronics II
16.604 Microwave Devices
16.605 Selected Topics in Semiconductors
16.700 Seminar

COURSES OF STUDY

16.502 Introduction to VLSI Design **(2-3)3**
Prerequisite: 16.365
A study of MOS device electronics, circuit forms and methodologies. Logic design techniques and system architectures. Lay out, fabrication and patterning technology for integrated circuits. SPICE models. Laboratory exercises.

16.503 Solid State Physical Electronics I **(3-0)3**

Prerequisite: 16.360 or consent of the instructor.

Introduction to the behavior of solid state devices. Review the Bohr's model of the atom, wave-particle duality, wave packets and Schroedinger's equation. Study of crytalline and amorphous materials. Band theory of solids; electrons and holes. Metals, insulators and semiconductors. Semiconductor behavior.

16.506 Antenna Theory and Design **(3-0)3**

Prerequisite: 16.461

Introduction of the fundamental principles of antenna theory; analysis, synthesis and design. Antenna parameters. Electromagnetic fields due to prescribed sources; near and far regions; reciprocity. Infinitesimal dipole. Arrays (patterns, mutual coupling). Array synthesis. Dipole, linear wire, loop, traveling wave, frequency independent, aperture and horn antennae.

16.507 Electromagnetics I **(3-0)3**

Prerequisite: 16.461

Maxwell's equations and boundary conditions. Electric and magnetic potentials. Static approximations, boundary value problems and solutions by separation of variable technique. Plane waves, dispersion, polarization, reflection and refraction. Guided waves, transmission lines and waveguides. Cavity resonators. Radiation by simple structures. Field and power calculations.

16.509 Linear Systems Analysis **(3-0)3**

Prerequisite: 16.362

Review of linear signal and system theory. The Fourier and bilateral Laplace transforms. The z-transform. Convergence properties. Discrete time Fourier series and discrete time Fourier transform. Filtering, modulation, sampling and stability.

16.510 Digital Signal Processing **(3-0)3**

Definition of discrete signals and systems. Difference equations. Representation of linear shift-invariant discrete systems. z-transform. Discrete Fourier transform and series. Digital filtering and digital filter design. Computation of the discrete Fourier transform. Discrete random signals.

16.513 Modern Control Theory **(3-0)3**

Prerequisites: 16.362 or 16.509 and 92.523 or equivalent.

The state-space, linear algebraic approach to linear time-invariant and time varying systems. Controllability and observability. Time domain design of feedback control systems; continuous time and discrete time systems.

16.519 Digital Control Systems **(3-0)3**

A study of systems which include digital microcontroller element(s) for real time processing applications. Case studies include systems in the areas of process control, flight control, air traffic and navigation systems, environmental and pollution control systems.

16.520 Applied Numerical Methods **(3-0)3**

Taylor series. Number systems and error. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability; Predictor-Corrector and Runge-Kutta methods. Orthogonal polynomials. Discrete transforms. Roots of Polynomials. Zeros and stationary points of single variable functions. Gradient, Quasi-Newton and conjugate gradient methods of optimization.

16.522 Data Structures **(3-0)3**

Prerequisites: FORTRAN and Pascal or instructor's permission.

Character strings, character substring searches; lists, their storage structure and uses; trees, tree searches, and storage concepts; compiling, Polish strings, translating from infix to postfix and prefix, conversion to machine code.

16.524 Programming Languages **(3-0)3**

Prerequisite: FORTRAN or Pascal

Syntax and semantics of programming languages. Fundamental concepts of control structures, modularity, scope of identifiers, recursion, and data structures are covered. Examples of real programming languages such as FORTRAN-77, Pascal, LISP, APL, and ADA are included.

16.525 Simulation Techniques **(3-0)3**

Prerequisites: FORTRAN, 16.366

A study of modern techniques for the simulation of continuous and discrete time systems and processes. Model building, simulation organization, statistical consideration and model validation will be discussed. The student is expected to study a number of physical and engineering systems through the use of simulation techniques on available computers. Semiconductor models, discrete and integrated.

16.531 Active Network Synthesis **(3-0)3**

Prerequisite: 16.366

Controlled sources. Impedance convertors and invertors. Synthesis techniques using the negative impedance convertor, the gyrator, and the operational amplifier. Active filter theory. Transcendental systems. Continued fraction expansions. Canonic realizations.

16.532 Computational Electromagnetics I **(3-0)3**

Prerequisite: 16.461

Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in elctrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method.

16.533 Microwave Engineering **(3-0)3**

Prerequisite: 16.461

TEM and Quasi-TEM transmission lines. Strip, microstrip, slot and coplanar lines. Rectangular and circular waveguides. Dielectric image line. Microwave circuit theory. Z,Y, scattering and ABCD parameters. Passive components. Ferrites. Microwave measurement techniques.

16.534 Microwave Laboratory **(2-3)3**

Prerequisite: 16.403 or 16.533

Measurement of frequency and wave length. Measurement of standing wave ratio and shift in minima. Measurement of dielectric constant for lossless and lossy dielectrics. Measurement of power. Measurement of return loss and S-parameters of a junction. Input impedance of an antenna over a ground plane.

16.537 Introduction to Bio-Medical Engineering **(3-0)3**

Prerequisite: 16.366

A survey of the use of engineering methods in the life sciences. Topics covered include instrumentation techniques and devices, computer diagnosis of disease, computer-aided data analysis, telemetry, ultrasonic techniques, artificial organs, prosthetic devices, biological modeling and simulation. Necessary biological background information is introduced as needed.

16.543 Theory of Communication **(3-0)3**

Prerequisite: 16.362 or equivalent

Information transmission and deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Statistical properties of noise. Spectral analysis and design of AM, FM and pulse modulation systems, continuous and discrete. AM, FM and various pulse modulation methods, in the presence of noise.

16.545 Coding Theory **(3-0)3**

Concepts and recent developments in the use of codes for error control in data handling systems. Encoding and decoding procedures and their implementation in computational algorithms and hardware organizations are investigated in detail.

16.548 Information Theory **(3-0)3**

Prerequisite: 92.386 or equivalent

Probabilistic measure of information. Determination of the information handling capacity of

communication channels and fundamental coding theorems. Introduction to information coding and error correcting codes.

16.561 Computer Organization and Design **(3-0)3**
Prerequisites: 16.217, 16.265
Structure of computers, past and present; first, second, third and fourth generation. Combinatorial and sequential circuits. Programmable logic arrays. Processor design: information formats, instruction formats, arithmetic operations and parallel processing. Hardwired and microprogrammed control units. Virtual, sequential and cache memories. Input-output systems, communication and bus control. Multiple CPU systems.

16.562 Microprogramming **(3-0)3**
Prerequisite: 16.217, 16.265
Basic computer organization including hardware resources, primitive basic computer operations and generation of control information. Evolution of microprogramming technique and a Simple Microprogrammable Machine (SMM). Overview of hardware components, control store design, timings, ALU design, main memory and data paths. Microinstruction design including vertical-horizontal and diagonal encoding characteristics for the SMM, as well as serial, parallel, monophase and polyphase clocking characteristics. Computer description languages with examples from bit-slice microprocessor design, emulators and simulators.

16.563 System Programming **(3-0)3**
Prerequisite: 16.217
The definition of system programming as programming in a multi-user environment. Programming with and for interrupts. Reentrant programming, pure procedures. Communication between program modules. Nested calls, the push-down stack. Recursive program calls. Reentrant interrupt programming. Activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, macro processes and introduction to assemblers and macro assemblers.

16.564 Operating Systems **(3-0)3**
Prerequisite: 16.217
The resources of a large computer system. Sequential and concurrent proceses in large digital computers. Design objectives: programming sharing, multi-programming, multi-processing, memory-sharing and protection. Process and communications and critical processes in operating systems. Scheduling, paging, segmenting and swapping stategies. Time sharing and multiple-task operating systems. Design and simulation of operating system behavior. Operating system performance evaluation. Introduction to the UNIX operating system with C language programming.

16.571 Radar Systems **(3-0)3**
Prerequisite: 16.439 or 16.543
Introduction to both pulsed and C.W. radar systems. Detection of radar echoes in noise. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Moving target indicators. Pulse compression and other advanced techniques. Discussion of elements of practical radar systems.

16.574 Introduction to Digital System Design **(3-0)3**
Prerequisites: 16.217, 16.265, 16.366
A review of combinatorial and sequential circuit concepts at both the bit and register levels, number systems, binary adders, shift registers, and memories. The definition of a basic set of control operations and data modules are used to develop a register-transfer-level language which is used to flowchart and document design algorithms. The algorithmic designs of special purpose MSI and LSI devices are studied and compared. Either hardware implementations or computer-assisted simulations, using SIMRTM, are conducted to assist in an elevation of the cost, performance, and adaptability of each design algorithm. Applications include asynchronous processing, parallel processing, stacks, queues, microprocessing, special purpose processors, and microcoded processor, and I/O interfacing techniques.

16.582 Radio Frequency Communication System Design (3-0)3

Prerequisite: 16.461

Ground wave, sky wave and tropospheric wave propagation of radio frequency signals. Line-of-sight communication and over-the-horizon radar systems. Design calculations for radio links between earth stations.

16.583 Wave Propagation In Plasmas (3-0)3

Prerequisite: 16.461

Interaction of electromagnetic radiation with plasma; specifically the earth's ionosphere. Concepts of refraction, reflection, dispersion, absorption and ray paths. Ionospheric effects on ground-to-ground and ground-to-satellite radio communication and over-the-horizon radar systems.

16.584 Probability and Random Processes (3-0)3

Axiomatic definition of Probability. Combined experiments. Bernoulli trials. Asymptotic theorems. Bayes theorems. Discrete and continuous random variables with functions of one or more random variables, and the continuous probability density function. Expected value, moments, characteristic functions, mean square estimation. Introduction to random processes. Time averages and ensemble averages. Autocorrelation function and power spectral density.

16.602 Advanced VLSI Design (3-0)3

Prerequisite: 16.502

Logic abstraction, digital circuit optimization techniques, clocks and communication design of array structures. The microarchitecture of VLSI systems. SPICE models for regenerative logic circuits and memories. Selected laboratory exercises.

16.603 Solid-State Physical Electronics II (old #16.504) (3-0)3

Prerequisite: 16.503

Semiconductor devices: Schottky diodes. p-n junction devices. junction transistors. FET's. Photo-diodes. Varactors. Electro-optic devices, thermo-electric devices, electro-luminescent diodes and laser diodes.

16.604 Microwave Devices (old #16.505) (3-0)3

Prerequisite: 16.503

Review of EM theory. p-n junctions. Varactors and SRD multipliers. Microwave transistors. Tunnel diodes. FET's. Transferred electron devices - Gunn diode. LSA avalanche diodes - IMPATT, TRAPATT AND BARITT diodes. Quantum electronic solid state sources - ruby masers and semiconductor lasers. Parametric and IR devices.

16.605 Selected Topics in Semiconductors (3-0)3

Prerequisite: 16.502 or 16.503

Advanced material processing; state of the art fabrication technology for integrated circuits, amorphous and liquid semiconductors. Comprehensive study of Ga-A1-As and Ga-In-As and super lattice structures.

16.607 Electromagnetics II (old #16.508) (3-0)3

Prerequisite: 16.507

Plane wave representation of electromagnetic waves. Angular spectrum of plane waves for two and three dimensions. Green's function method of solution for self adjoint boundary value problems. EM wave propagation in stratified media. Dyadic Green's function and applications.

16.608 Scattering and Diffraction of EM Waves (3-0)3

Prerequisite: 16.507 or equivalent

Review of EM Theory. Scattering from a long cylinder for TM and TE waves. Scattering pattern and crosssection. Scattering from a sphere. Rayleigh and Mie regions. Half plane and wedge diffraction. GTD and applications for high frequency scattering. Babinet's principle and diffraction by an aperture. Physical Theory of diffraction. Weiner-Hopf methods.

16.609 Inverse Scattering and Source Theory **(3-0)3**

Prerequisite: 16.507 and permission of the instructor.

Inverse scattering theory. Characterization of scatterer from the scattered wave. Synthesis of transmission lines with specified transmission and reflection properties. Inverse source theory; synthesis of sources to give prescribed radiating waves and signals. Soliton theory.

16.613 Nonlinear Control Systems (old #16.515) **(3-0)3**

Prerequisite: 16.513

Analytic and numeric methods for the analysis and design of nonlinear control systems. Phase plane, describing functions, the methods of Lyapunov and Popov and other techniques are treated.

16.614 Optimal Control Theory (old #16.517) **(3-0)3**

Prerequisites: (16.509) and 16.513

Deterministic optimal control systems. Performance measures for optimal systems. Dynamic programming and related computer techniques. Discrete linear regulator. The Hamilton-Jacobi-Bellman equation. Continuous linear regulator. Calculus of variations and Pontryagin's minimum principle. Minimum time problems. Minimum effort problems.

16.620 Robotics **(2-2)3**

Prerequisite: (16.509)

Movement and imaging under the homogeneous representation. Robotic joints. Classification and analysis of robots; inverse kinematic solutions. Parametric description of curves. Curved surfaces and triangular Bezier patches. Joint determination with curved surfaces. Introduction to artifial vision systems.

16.621 Computer Aided Design **(2-2)3**

Prerequisite: (16.509)

Closed and open form systems. Convergence strategies for open form systems. Nested programming methods and program structures. Data reduction and presentation. Applications to electrical networks and other physical systems.

16.637 Biological Systems (old #16.537) **(3-0)3**

Prerequisites: 16.413, 16.445, 16.537

A discussion of the application of modern control theory to the study of biological systems. Modeling and simulation techniques are emphasized. Necessary biological background information is introduced as required.

16.663 Compiler Structures (old 16.523) **(3-0)3**

Prerequisite: Pascal, 16.563

Translators and interpreters for programming languages. Syntax of programming languages, syntax directed compilation. Parsing techniques: operator precedence, top down, bottom up and reductive strategies. Intermediate forms and symbol tables. Generation and optimization of machine code. Error handling: detection and correction. The run time environment, storage allocation. Mathematics 92.569 may be substituted for this course.

16.661 Computer/Local Area Networking **(3-0)3**

Prerequisite: 16.561

Characteristics and topology of Local Area Networks (LAN's). Access control protocols. Standards. Design of cable plants. Digital data switch. Voice/data computerized CBX. Device/LAN interface. Performance and evaluation of LAN's and computer networking.

16.674 Digital Subsystem Design (old #16.575) **(2-2)3**

Prerequisite: 16.574

A continuation of the design process developed in 16.588 with emphasis on developing algorithms at the register transfer level, decomposition of these algorithms into detailed RTL flowcharts showing register transfers, control and timing sequences, using a standard bussing scheme. A hardware term project, of reasonable scope, is required of each student along with a complete report detailing the design and use of the project system, hardware and software.

16.675 Advanced Digital Devices (old #16.573) **(3-0)3**

Prerequisite: 16.574

State of the art microprocessors are examined and compared to their eight bit counterparts. The four architectional concepts of memory segmentation, operated addressing structure, operation register set, and instruction encoding scheme are evaluated between difficult families of processor design. Arithmetic and logical instruction support for high performance numeric processing requirements are discussed using numeric data processors.

16.676 Digital System Design Laboratory (old #16.576) **(2-3)3**

Prerequisite: 16.574

The objective of this course is to explore applications of digital devices and systems to realistic engineering problems. Students are required to design, and develop, build and test systems emphasizing current state of the art digital developments. This is a limited enrollment course and requires extensive time in the laboratory.

16.685 Statistical Communication Theory (old #16.547) **(3-0)3**

Prerequisite: 16.684 or permission of instructor

A study of statistical communication problems. Particular topics include the decription of signals and noise as stochastic processes. Signals, noise in demodulation. The continuous-time matched filter and Weiner filter. The multinomial Gaussian probability density and Gaussian derived densities.

16.686 Random Processes (old #16.585) **(3-0)3**

Prerequisite: 16.684

Definition of a random process. Bernoulli and Poisson processes, quadratic mean convergence, integration and differentiation of random processes; application to topics such as statistical filtering and estimation, queueing theory, reliability, communication theory, statistical physics.

16.687 Stochastic Estimation Theory and Applications (old #16.586) **(3-0)3**

Prerequisite: 16.685 or 16.686

A review of random vectors. Estimation theory for dynamic systems based on Bayesian and maximum likelihood methods. Discrete-time and continuous Kalman filter; with applications. Smoothing of dicrete-time signals, parameter identification and adaptive estimation.

16.700 Seminar (old #16.601) **(3-0)3**

Prerequisites: Minimum of 15 credit-hours of graduate courses; for students in the non-thesis option only.

Presentation of oral proposals on an advanced engineering topic; modified and redefined as required. Scholarly oral presentation of investigation outlined in proposal before the class and instructor. Grade based on clarity of exposition, knowledge of subject, ability to clearly and effectively answer questions, as well as participation in the discussions of other papers. Class size limited to ten students.

16.710-729 Selected Topics in Electrical Engineering (old # 16.651-659) **(3-0)3**

Prerequisites: Specified at time of offering.

Advanced topics in various areas of electrical engineering and related fields.

16.730 Electrical Engineering Thesis (old #16.701) **(0-9)6**

Prerequisites: Minimum of 15 credit-hours of graduate courses at an acceptable level; approval of a written proposal outlining the extent and nature of proposed research work.

The report on the research work, performed under the supervision of a faculty member, must be published in appropriate form and presented to a committee of three faculty members appointed at the time of acceptance of the thesis proposal. The student is required to give an oral defense of the thesis before the committee and other faculty members. The committee may recommend to the Graduate Affairs Committee that more than 6 credit-hours be granted for work of an exceptional nature.

16.731 Computer Engineering Thesis (old #12.701) **(0-9)6**
The same prerequisites and course requirements as in 16.730 apply.

16.732 Systems Engineering Thesis (old #28.701) **(0-9)6**
The same prerequisites and course requirements as in 16.730 apply.

DEPARTMENT OF INDUSTRIAL TECHNOLOGY

DEPARTMENT CHAIRPERSON: H. Jack Apfelbaum, *Professor;* B.M.E., City College of New York; M.S., University of Connecticut; Ed. M., Harvard University.

GRADUATE COORDINATOR: John D. Colluccini, *Assistant Professor,* B.S., M.S., University of Lowell.

FACULTY:
David A. Colling, *Associate Professor;* S.B., S.M., Sc D., M.I.T.
Lawrence A. Maloney, *Assistant Professor;* B.S., University of New Hampshire; M.S., Air Force Institute of Technology.
Nancy T. Miu, *Associate Professor;* B.S., National Taiwan University; M.S., North Dakota State University.
Donald S. Pottle, *Associate Professor;* B.S., M.S., Northeastern University.
G. Lawrence Thatcher, *Assistant Professor;* B.S., M.S., University of Lowell.
Robert J. Tuholski, *Assistant Professor;* B.S., Fitchburg State College; M. Ed., Ph.D, University of Maryland.
Peter S. Vail, *Assistant Professor;* B.S., Lehigh University; M.B.A., Xavier University.

MASTER OF MANAGEMENT SCIENCE IN MANUFACTURING ENGINEERING

The process of manufacturing is becoming more sophisticated and more automated. At the same time, industry is faced with managers who have little or no technical training or engineers whose background in the management aspects of the firm is often limited.

The program in Manufacturing Engineering is one that blends technology and management to produce a graduate comfortable in both areas. The program consists of a mix of manufacturing engineering courses and business/management/leadership courses. The graduates of this program will be well qualified to continue in a technical career or to use their dual skills to assume managerial roles.

ADMISSION

Applicants must have a B.S. degree in one of the following: Engineering (any discipline), Industrial Technology or Engineering Technology. Students with degrees in other areas are eligible to apply, but may have to complete a substantial number of prerequisite courses before beginning the program.

A student should have had an undergraduate course in each of the following:

- Statistics
- Accounting
- Economics
- FORTRAN (or other high level computer language)

DEGREE REQUIRMENTS
The degree will require 30 credit hours (33 for project option) with the study broken up as follows:

Course work -	24 credits	Course work -	30 credits
Thesis	6 credits	Project	3 credits
	30 total credit hours		33 total credit hours

Courses will be selected from a number of departments within the College of Engineering, Management Science, Pure and Applied Science and Liberal Arts. The list of selections is below. Other courses may be used upon approval by the Graduate Coordinator.

ENGINEERING
A total of 15 credits in engineering subdivided as follows:

Required:

20.416 - Statistical Quality Control
20.510 - Human Factors Engineering

Any two of the following 4 courses:

20.530 - Electronic Materials & Processes
20.515 - Automation
20.520 - Robotics
20.525 - Computer Integrated Manufacturing

Plus an additional free elective from the following list:

20.540 - Systems Concepts in Safety
20.535 - Microprocessor Applications
26.518 - Plastics Product Design
22.427 - Design of Automatic Machinery
22.421 - Computer Aided Design/Computer Assisted Manufacturing
22.463 - Fund. of Engineering Measurement, Instrumentation & Quality Control
16.525 - Simulation
16.522 - Data Structures
16.465 - Introduction to Microcomputers
91.541 - Robotics, Vision & Manipulation
91.545 - Computer Graphics
91.546 - Introduction to Computer Aided Design

MANAGEMENT

A total of 9 credits in management must be chosen from the following:

(Required) 60.612 - Managerial Accounting

Plus one elective from each of the following two groups:

66.651 - Organizational Behavior
(Pick one) 66.774 - Industrial Relations
66.652 - Human Resources Management
66.672 - Operations Management
66.673 - Operations Research
(Pick one) 66.602 - Information Systems for Management
20.414 - Industrial Economic Management
20.545 - Economic Forecasting for Industrial Managers

COURSES OF STUDY - COURSE DESCRIPTIONS

20.416 Statistical Quality Control **(3-0)3**
A study of the statistical and administrative techniques for maintenance of product quality at defined levels. Sampling plans for variables and attributes are considered from the viewpoint of consumer vendor relationships and economics.

20.510 Human Factors Engineering **(3-0)3**
Surveys the discipline of human factors and illustrates its importance in designing tools, equipment and other systems for more efficient, safe and tolerable human use. Equips students to consider human strengths and limitations in such physical aspects as movement and reach, and in such mental aspects as attention, perception, memory and cognition in the design of manufacturing systems.

20.530 Electronic Materials and Processes **(3-0)3**
Electronic, magnetic and semiconductor properties of materials used in the electronics industry. Manufacture of silicon chips, bonding and electronic packaging of integrated circuits, manufacture of printed wiring and assembly of printed circuit boards will be examined.

20.515 Industrial Automation **(3-0)3**
Motivation for automating. Sequencing. Automatic inspection movement. NC/CNC/DNC/CAM. Design for assembly and parts handling. Parts placement. Grouping technology. Basic systems concepts. People and automation issues.

20.520 Robotics **(3-0)3**
A thorough treatment of the technical aspects of robot technology. Advanced topics include geometry and kinematics of arm linkages, design of effectors, tactile sensing, robot vision and the role of artificial intelligence.

20.525 Computer Integrated Manufacturing **(3-0)3**
The current status and future role of computers, robots, automation and automatic data handling in manufacturing and related functions will be examined. Human and sociological factors related to the planning and implementation of computer integrated manufacturing will be reviewed.

20.540 Systems Concepts in Safety (3-0)3
The application of systems concepts are extended to the industrial safety field. Management modules, concepts, quality circles, human error concepts and, ergonomic considerations will be discussed in detail, using numerous case studies involving fire hazards, machinery safeguarding, material handling and slips and fall hazards.

20.545 Economic Forecasting for the Industrial Manager (3-0)3
The use of macroeconomic analysis and microeconomic analysis and how these tools can be used to control exogenous factors.

20.535 Microprocessor Applications (3-0)3
Microprocessor architecture, instruction set, addressing modes, program and memory requirements. Peripheral devices and interfacing techniques, with emphasis on control system applications.

20.414 Industrial Economic Management (3-0)3
Analysis of available alternatives in equipment, plant and materials purchasing or leasing. Economic feasibility analysis of industrial projects including depreciation techniques, break even analysis, cost-benefit techniques, replacement, present work and rate of return analysis.

(For additional course descriptions from other departments, see other appropriate sections of the graduate catalog.)

DEPARTMENT OF MECHANICAL AND ENERGY ENGINEERING

DEPARTMENT CHAIRPERSON: RICHARD MADDEN, *Professor;* B.S., M.S., Northeastern University; Ph.D., Virginia Polytechnic Institute.

MECHANICAL ENGINEERING PROGRAM

GRADUATE COORDINATOR: STRUAN R. ROBERTSON, *Associate Professor;* B.S., M.S., Clarkson University; Ph.D., Rensselaer Polytechnic Institute.

Faculty:

Gilbert J. Brown, *Professor;* B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology.
Majid Charmchi, *Assistant Professor;* B.S., Arya-Mehr University of Technology; M.S., Ph.D., University of Minnesota.
Craig D. Douglas, *Assistant Professor;* B.S.M.E., Lowell Technical Institute; M.S.M.E., University of Lowell; Sc.D., Polymerics, M.I.T.
John Duffy, *Assistant Professor;* B.S., Christian Brothers College; M.S., Illinois Institute of Technology; D.Sc., Washington University.
Richard A. Gaggioli, *Professor;* B.S., M.S., Northwestern University; Ph.D., University of Wisconsin.
C. Zelman Kamien, *Associate Professor;* B.S., M.S., Ph.D., Purdue University.
Kendrick W. Lentz, Jr., *Instructor;* B.S., M.I.T.; M.B.A., Northeastern University; M.S., M.I.T.

Jose G. Martin, *Professor;* B.S., Mississippi State University; M.S., Ph.D., University of Wisconsin.
John A. McElman, *Professor;* B.S., M.S., Northeastern University; Ph.D., Virginia Polytechnic Institute.
John McKelliget, *Assistant Professor;* B.Sc., Exeter University, U.K.; Ph.D., Sunderland Polytechnic, U.K.
Alan Mironer, *Professor;* B.M.E., Rensselaer Polytechnic Institute; M. Eng., Yale University; Ph.D., Syracuse University.
James A. Moore, *Associate Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., Massachusetts Institute of Technology.
Eugene E. Niemi, Jr., *Professor;* B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D. University of Massachusetts.
John C. O'Callahan, *Professor;* B.S., M.S., Ph.D., Northeastern University.
James P. Phelps, *Professor;* B.S., University of Maine; Ph.D., Michigan State University.
Steven Serabian, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Union College.
James R. Sheff, *Professor;* B.S., University of Colorado; M.S., Ph.D., University of Washington.
G. Dudley Shepard, *Professor;* B.S., Yale University; S.M., Sc.D., Massachusetts Institute of Technology.
John R. White, *Instructor;* B.S., University of Lowell, M.S., University of Tennessee.
Woon-Shing Yeung, *Associate Professor;* B.S., University of Lowell; M.S., University of California; Ph.D., University of California.
Yakov Zilberberg, *Associate Professor;* M.S. Technical Institute, Odessa, U.S.S.R.; Ph.D., University of New Hampshire.

DEGREE PROGRAMS IN MECHANICAL ENGINEERING

Master of Science in Engineering Degree Program

The Department of Mechanical Engineering offers a program leading to the master's degree with a thesis or project option.

The thesis option requires a minimum of 24 semester credits of course work and 6 credits of thesis work. The project option requires a minimum of 27 semester credits of course work and 3 credits of project work. In either case (thesis or projects) the work is guided by a committee of three faculty members. There is an oral defense for the thesis and the project. The written report must meet the same standards as that for the thesis.

Regardless of the discipline in which the student wishes to concentrate, he/she must take 6 semester credits in a core mathematics course, 3 credits in thermal-fluid processes and 3 credits in solid mechanics.

Retention Standards

Each student is expected to perform satisfactorily in his graduate work; 6 credits of BC and/or C together with a cumulative average of more than 3.0 will result in probation, i.e., reclassification from matriculated to provisional status. Six or more credits of BC and/or C together with a cumulative average of less than 3.0 will result in the student's being dropped from the graduate program:

Five Year Master of Science in Engineering Program

I. For students wishing to pursue the five year BS/MS Eng. pro-

gram, the first three years of course work is the same as that specified for students in the four year Bachelor's program.

II. In the senior year, the following modifications are involved.
   A. Students should take one graduate course per semester.
   B. Students should start their preliminary work on their thesis
   C. The students receive their B.S. degree after completing their senior year.
   D. In the fifth year, students take three graduate level courses per semester as well as 3 thesis credits per semester.

Ph.D. Program

A program offering a Ph.D. in Applied Physics with a concentration in Applied Mechanics is offered jointly by the Department of Physics and Mechanical Engineering. The program is structured as follows:

1. **General Required Courses**
   (a) Undergraduate courses include two semesters of Junior Electricity & Magnetism and two semesters of Junior Quantum Mechanics.
   (b) Graduate courses include two semesters of Mathematical Physics, one semester of Classical Mechanics and one semester of Thermodynamics & Statistical Mechanics.

2. **Qualifying Examination**
   The student must pass a comprehensive examination in Junior Mechanics, Electricity and Magnetism, and Quantum Mechanics after completion of part a.

3. **Thesis Requirements**
   A thesis proposal must be approved by a joint committee of the two departments. A student may not register for Graduate Research until he has passed the Ph.D. qualifying examination and the thesis proposal is approved. The thesis is to be based on original research performed under the supervision of a member of the graduate faculty and written to conform to the requirements of the Graduate School. Four legible copies of a typewritten original must be submitted to the Physics Department. Following this, the student must pass an oral examination, based on, but not necessarily limited to the thesis.

DOCTOR OF ENGINEERING PROGRAM

Whereas the Ph.D. program is narrowly focused on educating the specialist; the Doctor of Engineering program has the unique objective of educating engineers for leadership positions in industry, government and education. In addition to having a strong theoretical and technical thrust, the program places emphasis on technical management skills. The doctoral candidate will develop a program of study under the guidance of an advising committee. A key feature of this program is an internship in industry,

government or at the University during which time the dissertation is done. The dissertation, unlike the traditional research thesis, is directed toward the solution of actual design-development problems in an engineering environment. The candidate will use industrial or governmental resources and develop a close relationship with an industrial (governmental) advisor during the internship. The approach affords the student an opportunity to develop an appreciation for the balance between theoretical and practical aspects of engineering.

Admission Requirements
Applicants must have a Bachelor of Science degree in Mechanical Engineering or its equivalent and a 3.0 or better grade point average on a 4.0 scale. Alternatively, students already having a Master of Science degree in Mechanical Engineering or its equivalent may apply and transfer up to 24 course credits toward the doctoral degree.

Degree Requirements
For the Doctoral degree the basic breakdown consists of 44 credits of engineering courses, 15 credits of engineering management courses and 30 credits for the internship/dissertation. The engineering program must have a minimum of 6 credits each in engineering design, computer/programming and mathematics. The basic core requirement is the same as for the Master of Science degree.

There are four broad areas of faculty interest:

(1) Mechanics of materials which embraces such disciplines as composites, fracture, mechanical behavior of materials and non-destructive testing,

(2) Dynamics and Solid Mechanics which embraces vibrations, system dynamics, structural dynamics, continuum mechanics and finite element methods,

(3) Thermo-Fluids which embrace fluid mechanics, heat transfer, gas dynamics and computational fluid mechanics.

(4) Energy including nuclear and solar engineering as well as energy conversion.

A student will choose one of these broad areas as a main theme and will be required to take an additional 15 credits in that area.

There is no language requirement per se. However, if a student is interested in studying international business relations as part of the management sequence, language studies would be encouraged.

After completion of 24 credit hours of graduate engineering and mathematics courses the student takes a written qualifying exam, successful completion of which permits the student to continue in the Doctoral program. Upon completion of all course work the student becomes a candidate for the doctoral degree after passing an oral candidacy exam,

given by his committee. At this time, the candidate can initiate his dissertation/internship. This work is ususally carried on with close cooperation and support of industry or government.

Courses of Study

22-501 Graduate Seminar in Mechanical Engineering (0-0)0
A required weekly seminar intended to develop the oral communication skills of the student and an awareness of the research within the department. This seminar series is aimed at the Master's level student. Each student will present a 20-minute seminar each semester.

22-511 Matrix Methods in Engineering Mechanics (3-0)3
Matrix linear algebra, factorization of simultaneous equations, direct and iterating eigenanalyses, fortran programming and algorithm development, solutions in structural analysis, dynamics and stability using program MATRIX.

22-512 Structural Dynamics (3-0)3
Mass, damping and stiffness matrix development, static and dynamic condensation techniques, eigensolutions using MATRIX and structural analysis programs, modal superposition, maximum response analysis, direct intergration of motion equations, non-proportional damping.

22-514 Finite Element Analysis (3-0)3
Prerequisite: 22-562
Variational methods are used to derive the finite element equation for solid and thermal problems. Direct integration and modal methods are treated along with large deformations and inelastic behavior.

22-515 Modal Analysis I - Theory
System modeling using analytical and experimental techniques, frequency response functions, single and multiple dot curve fitting techniques, Fourier series and transform methods, DFT and FFT signal processing analysis.

22-516 Modal Analysis II - Experimental
Measurements using FFT based modal analyzers, structural modal surveys using impact and sine-sweep excitations, analytical modeling of test system, rotary dof estimation, complex modes, optimization of system matrices, structural modification procedures.

22-517 Experimental Methods in Vibration (3-0)3
Course focuses on the measurement of mechanical vibration. Topics include transducer selection, transducer design, signal conditioning. Typical measurement errors are discussed. Signal processing concepts are introduced.

22-518 Signal Processing Techniques (3-0)3
Course addresses the statistical processing of random vibration data. Fourier analysis and spectral concepts are presented. Correlation and coherence are discussed. Frequency response functions are introduced.

22-521 Advanced CAD/CAM (3-0)3
Prerequisite: 22-421
Fundamentals of CAD/CAM data bases, graphics manipulation and modeling. Interfacing data bases to CNC and other machines. Computer controlled machinery, automation and robotics.

22-522 Advanced Design Methods in Kinematics and Dynamics (3-0)3
Prerequisite: 22-421
Theory and application of computer models for the analysis of mechanisms. Use of analysis packages on a CAD system.

22-541 Fundamentals of Thermo-Fluid Processes **(3-0)3**
Governing equations (thermodynamic transport and kinetic); types of models; modes of solutions; data requirements and sources. Applications: fluid flow, heat and mass transfer, chemical reactions.

22-542 Advanced Engineering Thermodynamics **(3-0)3**
A comprehensive treatment of the first and second law. Availability, irreversibility, equilibrium, heterogeneous systems, mixtures and solution. Chemical equilibrium. Introduction to statistical methods.

22-543 Corrective Heat and Mass Transfer **(3-0)3**
Prerequisite: 22-541
Review of conservation equations. Heat transfer in laminar and turbulent boundary layer and duct flow. Free Convection. Convective mass transfer.

22-544 Conduction and Radiative Heat Transfer **(3-0)3**
Corequisite: 92-546
Steady and unsteady heat conduction: analytical and numerical solutions. Radiative heat transfer between surfaces and participating media.

22-545 Combustion **(3-0)3**
Prerequisite: 22-541
Thermodynamics of combustion. Dynamics of premixed and diffusion flames: ignition and extinction; flame propagation; combustion of solid and liquid fuels. Fire problems.

22-546 Energy Conversion **(3-0)3**
Concepts of thermodynamics pertaining to energy conversion; irreversible thermodynamics. Solid-state phenomena involved in conversion processes; energy forms, equations of states and energy fields. Selected topics in direct energy conversion systems.

22-547 Thermodynamic Analysis of Energy Systems **(3-0)3**
Prerequisite: 22-541
Second Law methods for pinpointing, quantifying and costing inefficiences in energy transfer and conversion systems, for improved and/or optimized systems operation and design.

22-551 Advanced Dynamics **(3-0)3**
Dynamics of rigid bodies and mixed mechanical, electrical and fluid systems using both direct and the variational based methods of Lagrange Equations and Hamilton's Principle.

22-552 Vibrations of Continuous Media **(3-0)3**
Prerequisite: 22-562, 92-545
Corequisite: 92-546
Generalized Fourier series and transform methods are applied to the solution of transient, free and forced motion problems in solids.

22-553 Random Vibration **(3-0)3**
Random processes; probability, time and ensemble averages, time correlation and power spectra. Applications to excitation and response of multiple input dynamic systems.

22-554 Dynamic Systems and Control **(3-0)3**
Matrix-based classical and modern approaches to dynamics and automatic control of hydraulic, thermal, electro-mechanical and structural dynamic systems with multiple inputs and outputs.

22-555 Fundamentals of Noise Control **(3-0)3**
Fundamental acoustic theory and measurement is presented. Baniers and sound absorption for control of airborne noise, vibration isolation and damping for structural noise are discussed.

22-561 Continuum Mechanics **(3-0)3**
Stress and deformation in a continuum in tensor notation. Fundamental laws of mechanics and

thermodynamics. Application to elastic viscous and viscoelastic substances.

22-562 Solid Mechanics I **(3-0)3**
The linear theory of elasticity is introduced followed by calculus of variations which is used as a tool for developing the variational principles of mechanism. Applications in structural mechanics include the study of torsion, beams, plates and shells.

22-563 Solid Mechanics II **(3-0)3**
Prerequisite: 22-562, 92-545
Corequisite: 92-546
Topics covered will include buckling, thermal stress, wave preparation and finite deformation.

22-564 Plates and Shells **(3-0)3**
Prerequisite: 22-562, 92-545
Solutions to bending, buckling and vibration problems are obtained for rectangular and circular plates. The membrane theory of shells as well as the general theory is investigated and solutions are obtained for a variety of practical shell problems.

22-566 Theory of the Inelastic Continuum **(3-0)3**
Prerequisite: 22-562, 92-545
Development of the constitutive equations governing inelastic (anelastic, viscoelastic, plastic and visco-plastic) deformations. Theorems and boundary value problems as applied to inelastic continua.

22-581 Advanced Fluid Mechanics **(3-0)3**
Corequisite: 92-545
Fundamental equations of fluid motion, kinematics, vorticity, circulation, Crocco's theorem, Kelvin's theorem, Helmholtz's vorticity laws, secondary flows. Stream function, velocity potential, potential flows. Unsteady Bernoulli equation, gravity water waves.

22-582 Viscous Flow **(3-0)3**
Prerequisite: 22-541
Derivation of Navier-Stokes equations. Examples of exact solutions. Laminar and turbulent boundary layer. Low Reynolds number flow.

22-583 Advanced Topics in Aerodynamics **(3-0)3**
Application of aerodynamic principles to one of the following topics: helicopter rotor aerodynamics, rocket flight, or aircraft performance. Topics may vary from year to year.

22-584 Two-Phase Flow **(3-0)3**
Fundamental development of one-dimensional two-phase flow. Homogenous flow, separated flows, drift flux model. Applications: gas-solid systems, gas-liquid systems, nuclear technology, wave propagation.

22-585 Turbulent Flow **(3-0)3**
Prerequisite: 22-541
Concepts of turbulence. Mixing length theory. Classical turbulent boundary layer, pipe and wake flows. Advanced turbulent models, and measurement techniques.

22-586 Computational Fluid Mechanics and Heat Transfer **(3-0)3**
Prerequisite: 22-541
Fundamentals of finite difference schemes: stability, consistence, accuracy. Spectral and Galerkin's methods.

22-587 Application of Special Numerical Methods in Thermo-Fluid Systems **(3-0)3**
Application of state-of-the-art numerical methods to the solution of problems involving fluid flow, heat transfer, chemical reaction and turbulence.

22-591 Mechanical Behavior of Materials **(3-0)3**
Prerequisite: 22-495

An examination of deformation mechanisms in solids and the study of such topics as brittle and ductile modes of fracture fatigue, creep, viscoelasticity, diffusion, friction and wear using actual case studies of failures.

22-592 Ultrasound, a Nondestructive Evaluation Method **(3-0)3**
Propagation characteristics of ultrasound are developed and analyzed to indicate usefulness as a nondestructive method of evaluation. Equipment for generation, detection and display are presented. Scientific and engineering applications using velocity and attenuation measurements are stressed.

22-594 Introduction to Fracture Mechanics **(3-0)3**
A first course in fracture mechanics covering topics such as brittle/ductile transition, Griffith criterion, energy approaches, COD and plastic zone sizes, the Gurney approach, numerical methods and the J-integral.

22-596 Composite Materials **(3-0)3**
The mechanical behavior of orthotropic materials is reviewed. Methods of analysing orthotropic lamina and laminated composites are introduced. Important methods of fabrication and testing of composites are covered. Other topics include environmental effects, joining and machining.

22-597 Structural Application of Composite Materials **(3-0)3**
Prerequisite: 22-562 or 22-564, 22-596

Study of constitutive relationships for anisotropic materials and application of these materials to structural elements such as beams, plates and shells. Problem areas considered include bending, buckling, and vibrations.

22-598 Case Studies in Composite Materials **(3-0)3**
Prerequisite: 22-514, 22-597

A third course in advanced composite materials. Individual cases are analysed such as bending, buckling and vibration of specially orthotropic places and angel ply laminates. Composite shells theory is reviewed and complex structures are studied.

22-601 Selected Topics in Mechanics **(3-0)3**
Advanced topics in mechanics not covered in the regular curriculum. Content may vary from year to year.

22-602 Special Topics in Thermo-Fluids **(3-0)3**
Advanced topics in thermo-fluids not covered in the regular curriculum. Content will vary from year to year.

22-603 Special Topics in System Design **(3-0)3**
Advanced topics in thermo-fluids not covered in the regular curriculum. Content will vary from year to year.

22-606 Directed Study **(3-0)3**
This gives the student the opportunity to learn material of an advanced nature in the format of a tutorial.

ENERGY ENGINEERING PROGRAMS

PROGRAM COORDINATOR: JAMES P. PHELPS, *Professor;* B.S., University of Maine; Ph.D., Michigan State University

GRADUATE COORDINATOR: JOSÉ G. MARTÍN, *Professor;* B.S., Mississippi State University; M.S., Ph.D., University of Wisconsin.

Faculty:

Gilbert J. Brown, *Professor;* B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology.

John Duffy, *Assistant Professor;* B.S., Christian Brothers College; M.S., Illinois Institute of Technology; D.Sc., Washington University (St. Louis).

James R. Sheff, *Professor;* B.S., University of Colorado; M.S., Ph.D., University of Washington.

John R. White, *Instructor;* B.S., University of Lowell; M.S., University of Tennessee.

DEGREE PROGRAMS IN ENERGY ENGINEERING

Research in Energy Engineering is carried out by several departments in the College of Engineering. Pinanski Hall houses some major engineering research facilities including a 1-Mw swimming pool research reactor and a 5 MeV van de Graaf accelerator. Extensive computing facilities support the ongoing work. Research interests include energy economics and safety, particle transport theory, reactor physics methods development, radiation damage, controlled nuclear fusion, solar thermal utilization, geothermal and wind energy utilization, cross section measurements, numerical analysis, nuclear fuel managment, waste management, and direct energy conversion.

Within the Department of Mechanical and Energy Engineering, the Energy Engineering program offers a Master of Science in Engineering degree with two options: Nuclear Engineering and Solar Engineering. For the first of these options, there is a special five-year Master of Science in Engineering program. At the doctoral level, the Department offers the Doctor of Engineering degree, and within the program leading to this degree it is possible to concentrate in either Nuclear Engineering or Solar Engineering. Finally, a program offering a Doctor of Philosophy degree in Applied Physics with a concentration in energy technology is offered jointly by the Department of Physics and the Energy Engineering Program.

Master of Science in Engineering Degree Program

The graduate program in Nuclear and Energy Engineering offers professional training at the master's degree level designed to provide an opportunity for the student to broaden and deepen his knowledge of various energy systems.

Credit Requirements and Thesis

Participants in the program may elect to follow a thesis or non-thesis option. The thesis option requires a minimum of 30 credit hours: 24 credit hours of course work plus 6 credit hours of thesis research. The non-thesis option requires a minimum of 33 credit hours: 30 credit hours of course work plus 3 credit hours of project work. A thesis must be defended in an oral examination conducted by the student's thesis committee.

Retention Standards

Each student is expected to perform satisfactorily in his graduate work; 6 credits of BC and/or C together with a cumulative average of less than 3.0 will result in probation, i.e., reclassification from matriculated to provisional status. Six or more credits of BC and/or C will result in the student being dropped from the graduate program.

Course Requirements
Students may choose to specialize in any area of energy interest in the College. Each student must take a series of core courses appropriate for his area of specialization. The exact makeup of the core curriculum will be guided and approved by the Graduate Committee of the Energy Engineering program. Two options are Nuclear Engineering, and Solar Engineering. In the first option, concentration can be in either fission or fusion.

All students working toward the M.S. Eng. degree in Energy Engineering must take the following courses:

22/24-509 System Dynamics
22/24-541 Fundamentals of Thermo Fluid Processes
22/24-504 Energy Engineering Workshop

The following courses are required for the Nuclear Option:

24-505 Reactor Physics
24-507 Reactor Engineering and Safety Analysis

For Energy Option, the following are normally required:

22/24-521 Fundamentals of Solar Energy Utilization
22/24-527 Solar Systems Engineering - Commerical and Industrial

The remainder of the course requirements are to be made up of elective courses. In addition to the course and credit requirements described above, all students working toward the M.S. degree are required to participate in the Graduate Research Seminar, 24-501/2.

Five Year Master of Science Program

For students wishing to pursue the five year B.S./M.S. program. the first three years of course work are the same as that specified for students in the four-year Bachelor's program. In the senior year, five-year students will take two graduate level courses as technical electives. These courses will be counted as undergraduate electives and, if a grade of B or better is attained, they may also be used for graduate credit. Students in this program will receive their B.S. degree after completing their senior year and the fifth year will consist of graduate course work and thesis/project research. Any additional graduate courses taken as overloads during the senior year may also be transferred for graduate credit.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

A program offering a Ph.D. degree in Applied Physics with a concentration in energy technology is offered jointly by the Department of Physics and the programs in Nuclear and Energy Engineering. The program is designed to develop advanced competence in physics and to provide professional training in engineering; this is a research degree. A (diagnostic) written Comprehensive Examination in fundamental undergraduate physics (classical

mechanics, electricity and magnetism, and, as appropriate, thermodynamics, statistical mechanics, quantum mechanics, modern physics) is to be taken upon entry to the first semester of the graduate doctoral program by students with a baccalaureate degree in physics, and by the third semester of the graduate doctoral program by non-physics majors. Later an oral examination (the Doctoral Admission Examination) based upon two semesters of #751/752 Advanced Research Projects and any graduate courses that have been taken up to that time is given. At least six courses (18 credits) of Energy Engineering or related engineering courses are required.

Other requirements for this program are specified under the "Doctor of Philosophy Degree in Applied Physics" section in the Physics Department description elsewhere in this catalog (specifically, note *Colloquia; Language Requirements; Other Skills; Comprehensive Examination;* and *Thesis Requirements*).

DOCTOR OF ENGINEERING DEGREE PROGRAM

The Department of Mechanical and Energy Engineering offers a Doctor of Engineering Program. Within this program, it is possible to concentrate in Solar Engineering or Nuclear Engineering. A student enrolled in this program should have a Bachelor of Science degree in Mechanical Engineering or its equivalent. The Department decides on what constitutes an equivalent: normally, a Bachelor of Science degree in Engineering is acceptable if the student can show competence in statistics, dynamics, and strength of materials.

The basic requirements for this degree are outlined elsewhere in this catalog under the degree programs for Mechanical Engineering. These include 44 credits of engineering courses, 15 credits of engineering management courses and 30 credits for the internship/dissertation. A student wishing to concentrate in either Solar or Nuclear Engineering must take the same four courses which are required from all students in this doctoral program before he takes a written qualifying examination. The rest of his course work is specified by the faculty advisor and approved by the graduate committee, taking into account the student's area of concentration.

Courses of Study

24-501, 24-502 Graduate Research Seminar **(1-0)1**
Presentation and discussion by faculty, invited speakers, and qualified graduate students of recent developments in the field of nuclear and solar engineering, energy policy and the financial and social costs of power. Required for all graduate students. Weekly meetings.

24-504 Energy Engineering Workshop **(3-0)3**
Prerequisite: Permission of Instructor
A group/individual design project. The design effort will integrate many aspects of the student's engineering background, including design concepts, technical analyses, economic and safety considerations, etc. A formal report and oral presentation are required.

24-505 Reactor Physics **(3-0)3**

Prerequisite: Permission of Instructor

Advanced treatment of several topics in reactor physics, including cross sections and processing methods, development of transport theory, reduction to diffusion theory, and analyses of analytical and numerical solutions of the resultant balance equations.

24-506 Special Topics in Reactor Physics **(3-0)3**

Prerequisite: Permission of Instructor

Potential topics include nodal methods, perturbation theory, data sensitivity and uncertainty analysis, fuel management and core optimization methods, noise analysis, space-time kinetics, reactor control, reactor safety, etc. May be repeated since topics vary.

24-507 Reactor Engineering and Safety Analysis **(3-0)3**

Prerequisite: Permission of Instructor

Modeling and analysis of reactor thermal-hydraulics/safety systems. Computer applications and NCR licensing criteria.

24-519 Reactor Operator Training **(0-6)3**

Prerequisite: Permission of Instructor

Training, including in-reactor experience and topical lectures, as given to Reactor Operator Trainees who will undergo Federal Testing for a Reactor Operator License.

24-520 Reactor Operator Training **(0-6)3**

Prerequisite: Permission of Instructor

Continuation of 24-519. Upon completion of this course, the student will be given a simulated Reactor Operator examination, including a written test, an oral test, and a controls manipulation test.

24-521 Fundamentals of Solar Energy Utilization **(3-0)3**

Prerequisite: Permission of Instructor

Solar radiation in space and on the earth's surface. Sunshape. Intensity and flux: effect of location and orientation. Review of heat transfer. Opaque and transparent bodies. Characterization of solar collectors/concentrators. A project is required.

24-522 Nuclear Materials **(3-0)3**

Prerequisite: Permission of Instructor

Review of metals and metal oxide properties. Radiation damage in fllids, plastics, ceramics, electronics, and graphite. Hardening, embrittlement, swelling, and creep in metals. Damage mechanisms. Shielding materials.

24-523 Numerical Methods in Eng. Analysis **(3-0)3**

Prerequisite: Permission of Instructor

Finite dimensional vector spaces, matrix algebra, finite difference equations and matrix iterative techniques. Applications involving the neutron diffusion and heat conduction equations. Description of the Monte Carlo and response matric methods.

24-524 Introduction to Solar Thermal Research **(3-0)3**

Prerequisite: 24-521, 24-527 or Permission of Instructor

Overview of solar thermal projects and concepts. Solar systems as lossy networks. Lessons learned and potential for improvement. Fuels and chemicals. Advanced concepts. A project is required.

24-525 Controlled Thermonuclear Fusion II **(3-0)3**

Prerequisite: 24-516 or Permission of Instructor

Intro to plasma physics. Particle orbit theory. The kinetic equation. Macroscopic description - static problems, waves, and instabilities. The Vlasoc equation - microscoptic instabilities. Transport coefficients.

24-527 Solar Systems Eng.—Commercial and Industrial (3-0)3

Prerequisite: Permission of Instructor

Concentrating collectors, thermal network modeling, passive design tools, photovoltaic systems, solar cooling, daylighting, solar ponds, and economics.

24-508 Special Topics in Reactor Engineering (3-0)3

Prerequisite: Permission of Instructor

Topics will deal primarily with reactor safety issues such as containment analysis, fission product release during accidents, probabilistic risk assessment, core concrete interactions, and standardized plant design.

24-509 System Dynamics (3-0)3

Prerequisite: Permission of Instructor

Mathematics foundation using the state-variable approach. Topics include matrix methods, Laplace and Fourier transforms, transfer functions, frequency response and stability analyses, and distributed/lumped parameter systems. Applications to thermo-fluid systems.

24-510 Nuclear Fuel Cycle (3-0)3

Prerequisite: 24-302 or 24-505

Discussion of the nuclear fuel cycle, including pre-irradiation, irradiation and post-irradiation steps of the fuel in a nuclear reactor. Evaluation of the components of the cost of electricity produced by a nuclear reactor.

24-511 Advanced Reactor Concepts (3-0)3

Prerequisite: 24-302 or 24-505

General characteristics. Breeding cycles and plutonium production, neutron balance, breeding ratio, and doubling time. Kinetic control and safety, sodium void and doppler coefficients. Design concepts.

24-512 Criticality Control (3-0)3

Prerequisite: Permission of Instructor

Consideration of safe practices in transportation, storage, handling, and use of fissionable materials. Effects of moderators, reflectors, and geometrics in thermal, epi-thermal, and fast assemblies. Natural and engineered safeguards.

24-514 Waste Management (3-0)3

Prerequisite: Permission of Instructor

History of Nuclear waste disposal, engineering design of disposal systems. Status of present waste and the character and quantities of future wastes. Review of disposal concepts on a generic basis. The national plan for waste disposal.

24-516 Controlled Thermonuclear Fusion I (3-0)3

Prerequisite: 24-416 or Permission of Instructor

Major approaches to controlled fusion. Fuel cycles. Sources and diagnostics. Confinement. Energy conversion: direct collection, electromagnetic coupling and thermal cycles. Fusion blankets.

24-518 Neutron and Gamma Transport Theory (3-0)3

Prerequisite: Permission of Instructor

Development and balance equations describing radiation transport. Analytical and numerical solution of the forward/adjoint integro-differential and integral Boltzman equations. Emphasis on discrete ordinates and Monte Carol methods as applied to radiation shielding.

24-529 Geothermal Energy (3-0)3

Prerequisite: Permission of Instructor

Systematic study of geothermal energy resources and their distribution. Economics of geothermal applications. One type of geothermal plant will be studied from concept through operation.

24-531/2 Selected Topics in Energy Science **(3-0)(3-0)6**
Prerequisite: Permission of Instructor
Individual research projects in a variety of topics in nuclear, solar or general energy engineering and technology. Emphasis is on state-of-the-art research methods in the particular field of interest. May be repeated with consent of advisor.

24-533 Windmill Applications **(3-0)3**
Prerequisite: Permission of Instructor
Introduction to the theory and engineering analysis of windmills. Included is consideration of the machine and machine types, the tower, energy conversion modes, and economic analysis. Consideration is given to state-of-the-art and existing machines and projects are reviewed.

24-535 Nuclear Instrumentation **(1-3)3**
Prerequisite: Permission of Instructor
Electrical test and measurement techniques using oscilloscopes, function generators and multimeters. Construction and test of circuits in nuclear instrumentation.

24-701/2 Graduate Research
Prerequisite: Permission of thesis advisor
Advanced research related to thesis work (minimum of six hours).

24-751/2 Advanced Projects in Energy Engineering **(3-0)(3-0)6**
Prerequisite: Permission of Instructor
Advanced research project required of all students electing non-thesis option (minimum of three hours).

DEPARTMENT OF PLASTICS ENGINEERING

DEPARTMENT CHAIRPERSON: NICK R. SCHOTT, *Professor;* B.S., University of California, Berkeley; M.S., Ph.D., University of Arizona.

GRADUATE COORDINATORS: RUDOLPH D. DEANIN, *Professor;* A.B., Cornell University; M.S., Ph.D., University of Illinois, and, **STEVEN J. GROSSMAN,** *Assistant Professor;* B.S., University of Connecticut; Ph.D., University of Massachusetts.

Faculty:

Everett S. Arnold, *Associate Professor;* B.S., Southeastern Massachusetts University; M.S., Lowell Technological Institute.
N. Bradford Brakke, *Adjunct Professor;* B.S., North Dakota State University; M.S., Butler University.
Sung J. Chen, *Associate Professor;* B.S., National Taiwan University; M.S., Ph.D., Kansas State University.
Aldo M. Crugnola, *Professor and Dean of College;* A.B., Boston University; M.S., Northeastern University; Sc.D., Massachusetts Institute of Technology.
Stephen B. Driscoll, *Professor;* B.S., M.S., Lowell Technological Institute.
Michael N. Helmus, *Adjunct Professor;* B.S., Lehigh University; M.S., Ph.D., Case Western Reserve University.
Jan-Chang Huang, *Assistant Professor;* B.S., National Taiwan University; Ph.D., University of Wisconsin-Madison.
William Kyros, *Associate Professor,* B.S., University of Lowell; M.S., Massachusetts Institute of Technology; Ph.D., Cornell University.
Stephen P. McCarthy, *Assistant Professor;* B.S., Southeastern Massachusetts University; M.S.E., Princeton University; Ph.D., Case Western Reserve University

Robert E. Nunn, *Associate Professor;* B.Sc., London University; A.C.G.I., Imperial College; D.I.C., Imperial College; Ph.D., London University.
Stephen A. Orroth, Jr., *Professor;* B.S., M.S., Lowell Technological Institute.
Stephen P. Petrie, *Associate Professor;* B.S., M.S., Lowell Technological Institute; Ph.D., University of Connecticut.
Amad Tayebi, *Professor;* B.S., Alexandria University; M.S., M.E., Sc.D., Massachusetts Institute of Technology.

Doctor of Engineering Degree Program

The Doctor of Engineering in Plastics Engineering is designed to produce qualified professionals for technical management positions in the plastics industry, as well as for administrative positions in government and for teaching careers in colleges and universities.

Admission to the Program

Graduates with a B.S. in Plastics Engineering and high academic standing may apply to the Graduate School for admission to the program. Graduates from other schools or in other fields of engineering will be required to make up any prerequisites which they lack in comparison to the B.S. Plastics Engineering curriculum at the University of Lowell. Technical graduates who do not have a B.S. in engineering may request admission to the program, on the understanding that they will also be required to make up the general mathematics, science and engineering courses which they lack. Admission to the program will be based on review by the Graduate School and by the Admissions Committee of the Plastics Engineering Department.

Plan of the Program

After satisfying the prerequisites and taking one year of graduate courses, the student will take a qualifying examination covering all the basic elements of plastics engineering. Students who perform well on this examination will be reviewed by the Admissions Committee of the Plastics Engineering Department. Students who satisfy these two criteria will be admitted to candidacy for the degree. They will then complete the remaining course work, seminars, internship, dissertation, and oral defense of their work.

Curriculum

The following courses are recommended for the degree:

26-503	Mechanical Behavior of Polymers	3
26-506	Polymer Structure, Properties and Applications	3
26-509/510	Plastics Processing Theory I/II	6
26-513	New Plastic Materials	3
26-518	Plastic Product Design	3
26-541	Computer Applications in Plastics	3
26-547/548	Mathematical Techniques & Numerical Techniques	6
26-858/586	Computer Aided Engineering and Design	6
26-601/602	Plastics Seminar	2
Engineering Electives		8
Engineering Management Courses and Seminar		17
Internship and Dissertation		30

Students who have already covered any of this material may substitute other engineering electives, with the advice and approval of their advisory committee. Students who have taken any of these courses toward the Master of Science degree may apply them toward the Doctor of Engineering degree as well.

Internship and Dissertation

Each student will be required to complete an internship of one year's duration in either industry, government or the University. The purpose of the internship is to place the student in a realistic engineering setting in which he or she will function as a high level engineer and carry out the work required for his or her dissertation. During the internship the student will maintain close contact with the academic advisor. The student will have, in addition, a close working relationship with the advisor provided by the organization sponsoring the internship. The dissertation problem will be design or development oriented, using these terms in their broadest engineering meanings.

The student will prepare a complete written dissertation on his or her internship, and make an oral defense to the advisory committee, which will include a representative from the staff of the internship organization. This defense will be open to the university community.

Other Requirements

Students must maintain high academic standing throughout the pursuit of the degree. They must spend at least one year at the University with full-time graduate student status, in addition to the internship requirement.

Master Of Science Degree Programs

The graduate programs offer professional training at the Master of Science level designed to provide the opportunity for the study of more advanced theory and practice in plastics, manmade fibers, coatings, and adhesives, and to broaden the background of experienced members of the profession and to help them keep up with the latest fundamental developments in the field.

Admission Requirements

Admission to the program is open to candidates with a B.S. in plastics engineering or a related field. Candidates with degrees in other fields of science or engineering, from other schools, or industrial experience in place of University of Lowell B.S. courses in plastics, will take the undergraduate courses they lack as prerequisites before undertaking the graduate courses in plastics. The G.R.E. Aptitude test is required for this program; but not the Advanced test.

Advisors and Advisory Committee

The program coordinator will be the academic advisor for each student, to help him remedy deficiencies in prerequisites, select electives of most value to him, and plan his overall study program efficiently. The thesis advisor will be chairman of the thesis advisory committee, which will guide the

student in his thesis research and supervise the completion of his thesis requirement.

Plastics and Plastics Engineering
Students with a B.S. in Plastics Engineering may earn an M.S. Eng. in Plastics Engineering by the following course of study:

26-5XX	Electives	22 Credits
26-601/2	Plastics Seminar	2
26-701/2	Graduate Research and Thesis	6

This should normally take three semesters.

Students with a B.S. in other fields of science or engineering may earn an M.S. in Plastics by making up the following prerequisites in addition to the above program:

Polymer Science
Polymeric Materials
Mechanical Behavior of Polymers
Physical Properties Laboratory
Process Engineering
Processing Laboratory

They may earn an M.S. Eng. in Plastics Engineering by also making up as well any missing prerequisites in mathematics and general engineering. This should normally take a total of four semesters.

Combined B.S./M.S. Eng. Degree Program

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, the College of Engineering and the Graduate School have established a program of accelerated study which leads to a master's degree in Plastics Engineering.

To be eligible to enter this course of study, the student must file a formal Graduate School application in the junior year. This does not require the student to take a GRE examination.

Students taking full advantage of the combined program ordinarily would be expected to finish the M.S. Eng. degree at the end of the fifth year of study. However, this will depend upon the student's course load and thesis work. A more detailed description of this program is found in the beginning of this catalog.

Students admitted to the program will be allowed to use 8 credits taken in the senior year toward their M.S. Eng. degree. The 8 senior credits would come from the following sequence:

Fall Semester
26-411 Senior Seminar: Take 26-601 Graduate Seminar instead.
Undesignated Elective: Take Graduate Plastics elective.

Spring Semester
26-412 Senior Seminar: Take 26-602 Graduate Seminar instead.
Undesignated Elective: Take Graduate Plastics elective.

During the summer preceding the fifth year the student is expected to start his/her thesis research. The student then can complete 16 credits of electives and 6 credits of research during the fifth year and use the summer months to complete thesis work if necessary.

Students with a light load in the senior year could take more graduate courses and/or thesis work during that year, thus further accelerating their program.

Manmade Fiber

This specialized course of study is designed to prepare prospective M.S. Eng. candidates for careers in the fiber producing, the fiber processing, and the fiber reinforced plastics industries.

Admission to the program is open to students with an undergraduate degree in plastics, textiles, or other applicable field of study (mechanical or chemical engineering, applied physics or chemistry). The student's Advisor will review his individual background to determine any further necessary prerequisites.

The curriculum includes 16 units of common/core courses, 2 units of seminar, 8 units of suggested electives and a 6-unit thesis in an area of current interest to the synthetic fiber industries.

Core Courses (16 Units)

97-503	Advanced Polymer Science I	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
26-503	Mechanical Behavior of Polymers	(3-0)3
26-504	Polymer Proc./Morphology/Properties	(3-0)3
26-509	Plastic Processing Theory	(3-0)3
26-525	Processing of Synthetic Fibers and Fiber Structures	(2-2)3

Elective Courses

26-506	Polymer Structure/Properties/Applications	(3-0)3
26-516	Reinforced Plastics/Composite Materials	(3-0)3
26-526	Adv. Proc. Synthetic Fibers and Fiber Structures	(3-0)3
26-527	Mechanics of Fibrous Structures	(3-0)3
26-528	Knitted and Non-Conventional Fiber Structures	(2-2)3
26-529	Fiber Evaluation	(2-2)3
26-530	Intro. Fiber Market/Management/Plant Organization	(3-0)3

Coatings and Adhesives

A complete curriculum in Coatings and Adhesives is open to graduates in chemistry, chemical engineering, coatings, plastics, or related fields, with experience or interest in the coatings field. The following curriculum is recommended:

26-533/4	Coatings Science and Technology I and II	(3-0)(3-0)6

97-503/4	Advanced Polymer Science I and II	(3-0)(3-0)6
97-505/6	Polymer Preparation and Characterization	(0-4)(0-4)2
26-503	Mechanical Behavior of Polymers	(3-0)3
26-536	Rheology	(3-0)3
26-532	Adhesives and Adhesion	(3-0)3
26-601/2	Seminar	(1-0)(1-2)2
26-701/2	Graduate Research: Thesis	(0-9)(0-9)6

Considering the varying background and interests of individual students, this basic curriculum can of course be modified by agreement between the student and his Advisory Committee.

Doctor of Philosophy Degree Program

A doctoral program in Chemistry with an option in Polymer Science/Plastics Engineering is offered jointly with the Polymer Science group in the Department of Chemistry. This program is designed to provide the student with a background in advanced course work and laboratory techniques that will prepare him to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires from three to four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary advisor).

All students entering the program must take the ACS Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503/504.

Requirements for Admission, Language and Area Examinations

Requirements for admission into the program are the same as for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Language and Area Examination requirements are the same as those for students in the Ph.D. Programs in Chemistry and may be found in this catalog under that program.

Course Requirements

Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required, with a minimum of four courses to be taken in chemistry and polymer science (84 and 97 prefixes) and a minimum of three courses to be taken in plastics engineering (26 prefixes), as listed below. The remaining course credits may be chosen from other graduate courses in chemistry, polymer science, and plastics. Credit

normally is not allowed for undergraduate subjects except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student's advisory committee and must include advanced subjects in the appropriate areas of chemistry, polymers, and plastics. When it is necessary to carry less than the normal credit load of 8 per semester, the student must apply to the chairman of the department through the chairman of his/her advisory committee for approval.

Required Courses

The student must take the following core courses:

84-523	Organic Reactions	(3)
	or	
84-568	Structural Analysis	(3)
84-531	Advanced Physical Chemistry	(3)
97-503	Advanced Polymer Science I	(3)
97-504	Advanced Polymer Science II	(3)
97-505	Polymer Preparation and Characterization I	(1)
97-506	Polymer Preparation and Characterization II	(1)
97-512	Bulk Properties of Polymers	
	or	
26-503	Mechanical Behavior of Polymers	(3)
26-506	Polymer Structure, Properties, and Applications	(3)
26-509	Plastics Processing Theory I	(3)
26-510	Plastics Processing Theory II	(3)

In addition, the student must take 84-515 (Chemical Literature 2 credits) and must register for Polymer Seminar (97-602) each semester.

The remaining formal course credits may be chosen from the graduate courses offered in polymer science and plastics engineering, with permission of the Dissertation Committee.

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1. Complete the first year's core of recommended subjects and have a satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. Complete the course credit requirements.
3. Pass the area examinations.
4. Fulfill the language requirements.
5. Secure the approval of his/her advisory committee and the graduate coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the graduate coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

26-502 New Plastics Processing Techniques* **(3-0)3**
Critical examination of new plastics processing techniques appearing in the research literature and being commercialized in the plastics industry.

26-503 Mechanical Behavior of Polymers **(3-0)3**
Mechanical properties of bulk polymers. Linear viscoelasticity, creep, relaxation, dynamic and stress/strain response phenomena. Principles of time/temperature superposition. Rubber elasticity. Failure behavior of polymeric materials.

26-504 Physical Properties of Polymers* **(3-0)3**
Polymers as linear viscoelastic materials. Creep, stress relaxation, superposition, dynamic mechanical behavior, electrical behavior, miscellaneous mechanical properties, optical properties, transport properties.

26-506 Polymer Structure, Properties, and Applications **(3-0)3**
Relationships between polymer structure (chemical composition, molecular weight and flexibility, intermolecular order and bonding, supermolecular structure) and practical properties (mechanical, acoustic, thermal, electrical, optical and chemical) and applications.

26-507 Plastics Industry Organization **(3-0)3**
Economics of producing plastic raw materials and converting them into end products, from research and development to plant construction, and marketing. Market analysis of plastics production, processing, and consumer patterns; commercial development, sales, and technical service. Organization of the Plastics industry for research and development, specialty and commodity production, profit, and growth.

26-509, 510 Plastic Processing Theory **(3-0)(3-0)6**
Principles of heat transfer, rheology, mixing, crystallization, and chemical reactions involved in the processing of plastics, and their applications to plastics process engineering.

26-511 Polymer Blends and Multiphase Systems* **(3-0)3**
Physical, mechanical and thermal properties, preparation, and testing of polymer blends, alloys, and multiphase systems. Thermodynamic theories and experimental determination of miscibility of polymer blends. Structure-property relationships for multiphase systems and interpenetrating networks.

26-512 Plastics Foams* **(3-0)3**
Preparation, structure, and properties of plastics foams. Practical systems in development and production. Properties, applications, and markets for plastics foams and products made from them.

26-513 New Plastics Materials* **(3-0)3**
Critical examination of the new plastics appearing in the research literature and being field-tested for commercialization in the plastics industry.

26-516 Composite Materials **(3-0)3**
The potential of composites as a class of materials, and the uniqueness of the mechanical/physical properties realizable. Fundamental concepts underlying those properties, with particular emphasis on fibrous reinforced plastics. Survey of matrices, reinforcements, and prediction of composite properties from a knowledge of properties and topology of constituent materials. Factors affecting ultimate strength and fatigue behavior.

26-518 Product Design **(3-0)3**
Theoretical principles and sound engineering practice involved in the design of new end products made from polymers, applying the total systems approach to the balance between product

design, choice of materials, and process technique, as they affect competitive choice for commercial success.

26-521 Polymerization Engineering* **(3-0)3**
Engineering design of equipment and plants for polymer production. Processes for production of each of the major commercial polymers.

26-523 Plastics Process Design, Analysis, and Simulation **(3-0)3**
Calculations and simulations of batch and continuous processes. Dimensional analysis. Thermodynamic properties of thermoplastics. Enthalpy, heat capacity, sensible heat, heat of fusion, and heat of reaction. Scale-up and modelling of processes.

26-524 Process Analysis, Instrumentation, and Control* **(3-0)3**
Industrial instruments for measurement and control of plastics processes. Design of experiments. Analysis of plastics forming operations. Dynamic testing techniques. Automatic plastics process control. Modeling and process simulation in extrusion and injection molding. Data acquisition systems.

26-525 Processing of Synthetic Fibers and Structures* **(2-2)3**
An introduction to systems utilized in the processing of synthetic fiber structures. These include drawing, winding, texturing, staple fiber production, blending, static control, dyeing and finishing. The effect of these mechanical, physical, and chemical processes on the resultant fiber and fiber structure behavior.

26-526 Advanced Processing of Synthetic Fibers and Fiber Structures* **(3-0)3**
A continuation of 26-525 to include a more detailed view of the processes and effects involved.

26-527 Mechanics of Fibrous Structures* **(3-0)3**
Characteristics of fibers as affecting performance of conventional and non-conventional fibrous structures. Design considerations and mechanical behavior of twisted, knitted, woven, braided, and nonwoven fibrous materials.

26-528 Knitted and Non-Conventional Fiber Structures* **(2-2)3**
Nonwoven materials and unusual fiber structures such as needle-punched, stitch bonded, and ultrasonic welded structures. Problems are assigned for laboratory evaluations and written reports as well as oral presentation are required.

26-529 Fiber Evaluation* **(2-2)3**
Basic mechanical tools, techniques and their utilization by industry for research, development, production control and end use evaluation. Moisture equilibrium and rates of change relations, basic fiber, yarn and structure dimensions; and an introduction to the determination and evaluation of the stress-strain-time properties of fibers and fiber structures; wear and abrasion are among the topics considered.

26-530 Introduction to Fiber Marketing, Management and Plant Organization* **(3-0)3**
An introduction to basic principles in the marketing, management, and plant organization of synthetic fibers. Consideration of distribution channels, costing, sales forecasting, management recruiting and machinery layouts.

26-531 Survey of Synthetic Fibers and Fiber Structures **(3-0)3**
General discussion of the basic problems encountered in the synthetic fiber industries, including fiber and fiber structure properties, processing, utilization and various aspects of current research. Recent advances and projected developments.

26-532 Adhesives and Adhesion* **(3-0)3**
Adhesive joining of engineering materials. Surface chemistry, theories of adhesion and cohesion, joint design, surface preparation, commercial adhesives, rheology, equipment, testing, service life, and reliability.

26-533, 534 Coatings Science and Technology* (3-0)(3-0)6
Polymers, pigments, solvents, and additives used in coatings. Methods of polymerization, formulation, application, and testing. Substrates and applications.

26-535 Rubber* (3-0)3
Polymerization and compounding of the commercial elastomers. Properties and test methods. Leading applications and methods of processing.

26-536 Rheology of Coatings* (3-0)3
Rheology of polymer melts, solutions, latexes and pigment dispersions, and their application to coatings and adhesives.

26-537 Engineering Properties of Plastics* (3-0)3
Theoretical basis and practical significance of the mechanical, thermal, electrical, optical, and chemical properties of plastic materials. Importance of engineering properties in material development and selection and in product design.

26-540 Commercial Development of Polymeric Material Systems* (3-0)3
The concepts of industrial marketing will be reviewed for research, pricing strategies, and product planning for market segmentation, place (distribution)-promotional activities. Topics will include creating a demand, selling, and servicing base resins and additives.

26-541 Computer Applications* (3-0)3
An introduction to microprocessor programming and interfacing. Programming includes logic operations, branch and jumps, and subroutines. Interfacing includes input and output, data acquisition systems, and controller design.

26-543, 544 Survey of Plastics Materials (3-0)(3-0)6
Descriptive course centering on the historical development of polymeric systems, their synthesis, structure, properties, and applications. Included will be a brief discussion on the typical additives employed to make plastics molding compounds. Not open to B.S. Plastics Students.

26-545 Methods of Experimental Analysis* (3-0)3
Methods of efficient design and analysis of scientific and industrial processing experiments. Classical vs. factorial experiments, statistical distributions and statistical inference, single and multifactorial analysis, interaction, correlation and regression.

26-546 Mixing in Plastics Processing* (3-0)3
Solids mixing, mixing in viscous fluids, admixing, concept and techniques of residence time distribution, continuous and batch processes, improvement of extrudate quality, scale-up and theory of similarity, dispersion and distributive mixing, mixing and heat transfer.

26-547 Mathematical Techniques for Plastics Engineers (3-0)3
Vector and tensor analysis, matrices and determinants, vector differential calculus, Lapace and Fourier transforms, power series, partial differential equations, introduction to numerical analysis. Use of the above techniques in plastics engineering calculations.

26-548 Numerical Techniques for Plastics Engineers* (3-0)3
Use of numerical methods in the solutions of problems concerning rheology, heat transfer, diffusion, and viscoelastic theory. Topics include solutions to ordinary differential equations, simultaneous linear equations, finite difference methods, finite element methods, plotting, linear regression, linear interpolation, curve fitting and optimization techniques.

26-549 Nylon Plastics* (3-0)3
Prerequisite: 84-223/224
Plastics applications for nylons have become extensive and this course will trace the development of what is considered the first engineering thermoplastic. A chronological sequence from monomer synthesis to polymerization, characterization, processing, properties, and applications.

26-550 Plastics Synthesis* **(3-0)3**
Prerequisite: 84-223/224
A balanced treatment of all types of reactions used to synthesize plastic materials. Kinetic features of step, chain, and ring-opening polymerizations, their scope and utility for commerical production.

26-551 Polymer Solution Systems* **(3-0)3**
Thermodynamics of polymer solutions. Polymer blends. Devolatilization. Diffusion and rheological properties of polymer solutions. Gel permeation chromatography and related polymer characterization methods.

26-552 Design of Polymer Processing Machinery* **(3-0)3**
Hydraulics, pneumatics, machine logic, drives, pumps, motors, heating and cooling, barrel and screw combinations, mechanical design, quick mold change, robots and interfacing.

26-555/556 Rheology and Characterization Practicum **(2-3)(2-3)6**
Practical review of theorectical concepts of rheological measurements with practical applications of experimental techniques. Emphasis will be on the viscoelastic properties of polymer solutions, melts, and solids with correlation with theorectical dynamic mechanical behavior.

26-557 Composites Fabrication I **(2-2)3**
Introduction to resins and reinforcements. Fabrication of thermoset composites. Hand lay-up, vacuum bagging, autoclaving, compression molding, rheological testing. Design concepts, product management, quality control.

26-558 Composites Fabrication II **(2-2)3**
A continuation of 26-557 with emphasis on a semester project on design, processing, and economics of composites.

26-559 Elements of Packaging* **(3-0)3**
Packaging methods, materials, and container designs. Analysis of container manufacturing methods for paper, plastics, cans, cardboard and their specific properties.

26-583 Research Methodology* **(3-0)3**
A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving and student presentation of data are stressed. Extensive reading of research papers, analysis of such and defense of the analysis is required.

26-585/586 Computer Aided Engineering and Design* **(3-0)(3-0)6**
Prerequisite: 22-421
Design of plastic components and molds. Finite element programs to perform linear and nonlinear stress analysis. MOLDFLOW program for detailed mold design.

26-601, 602 Plastics Seminar: Literature **(1-0)(1-0)2**
Survey of the technical literature in plastics, and techniques for searching it. Each student will carry out one literature research project per semester and report it to the class.

26-603, 604 Plastics Seminar: Current Journal Literature* **(1-0)(1-0)2**
Survey of the technical journals which carry reports of current advances in plastics science and engineering. Each student will report to the class on a portion of the current journal literature.

26-605, 606 Plastics Seminar: Research* **(1-0)(1-0)2**
Reports and discussions on current research in the department. Faculty and students will take turns presenting their current research activity, and turn to group discussion for guidance in solving their problems and planning their future work.

26-651/652/653/654 Selected Topics in Plastics **(3-0)(3-0)(3-0)(3-0)12**
Advanced topics in the various fields of plastics. Content may vary from year to year so that

students may, by repeated enrollment, acquire a broad knowledge of contemporary plastics.

26-701/702 Graduate Research in Plastics **(0-9)(0-9)6**
Individual research projects in plastics chemistry, properties, processing, products, and industry organization.

26-751/752/753/754 Advanced Projects in Plastics **(0-3)(0-3)(0-3)(0-3)4**
Special projects undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by Department Chairperson.

*These courses are given only when there is sufficient demand.

INTERDEPARTMENTAL DOCTOR OF ENGINEERING CURRICULUM

COORDINATOR: MAXIMILIAN M. ETSCHMAIER, *Professor of Engineering,* Dipl. Ing., Dr. Techn., Technical University of Graz, Austria; M.S., Case Institute of Technology.

Faculty:

B. Bruce Carroll, *Visiting Professor;* B.A., University of Vermont; M.P.A., Wayne State University; Ph.D., University of Chicago.
Stuart Freedman, *Assistant Professor, Management;* B.A., City University of New York; M.S., Ph.D., Cornell University.
John G. Hamer, *Assistant Professor, Accounting;* B.S., University of Lowell; M.B.A., Ph.D., Texas A & M University.
Robert E. Innis, *Professor, Philosophy;* A.B., St. Mary's College; S.T.B., Gregorian University; A.M., Ph.D., Fordham University.
Timm L. Kainen, *Associate Professor, Management;* B.A., Connecticut State University; M.A., University of Hartford; Ph.D., University of Massachusetts.
Ronald B. Pickett; *Associate Professor, Psychology;* B.A., Dartmouth College, M.A., Ph.D., University of Michigan.
Rudolph Winston, *Associate Professor, Management;* A.B., Haverford College; M.B.A., Columbia University; D.B.A., Harvard University.

The Doctor of Engineering programs are designed to educate engineers who, in addition to technical skills, possess the necessary breadth to lead large engineering projects and organizations and to assume leadership roles in the engineering profession. In order to accomplish this, a candidate for the Doctor of Engineering degree is required to take fifteen credits in subjects outside his/her engineering discipline and to attend a two-credit seminar. These courses and the seminar are common to the doctoral programs of all engineering departments and are administered at the College level. They cover the following subject areas: Large System Design; Behavioral Science and Leadership; Business Management; Law and Ethics; and Systems Analysis and Operations Research.

The courses are divided into three core courses required of all students and two electives which, with the advisor's consent, may be selected from a list of approved courses. The core courses are as follows:

25-620 Accounting
25-630 Law/Ethics
25-640 Organizational Behavior

These courses have been specially designed to meet the needs of an engineering professional. They are taught at a level corresponding to the exceptional caliber of Doctor of Engineering students and present the course material in a highly concentrated manner. Each course includes a guide to further study in the subject area, either through self study (literature) or through formal course work at the University of Lowell and elsewhere. Each course also provides an introduction to the profession concerned with the subject area. Specific instruction is given on when and how to use a specialist, how to identify a qualified specialist, and how to judge the work of a specialist.

The approved list of courses from which the student may select the remaining two courses of the interdepartmental program consists of courses which have been specially designed for the Doctor of Engineering program, and of standard graduate courses in the College of Engineering and in other parts of the University. The following list contains the currently approved courses. Courses not included in this list may be selected by special permission.

1. Courses specially designed for the Doctor of Engineering program
   - 25-540 Philosophy of Engineering
   - 25-660 Large System Design, Course
   - 25-661 Large System Design, Project
   - 25-530 Engineering Systems Analysis
   - 25-670 Quantitative Methods of Operations Research - Probabilistic Models
   - 25-675 Quantitative Methods of Operations Research - Deterministic Models
   - 25-510 A Systems Approach to Maintenance
   - 25-520 Transporation Systems Analysis

2. Other Available Courses in the College of Engineering
   - 16-584 Probability and Random Variables
   - 16-585 Random Processes
   - 16-525 Simulation Techniques
   - 16-540 Urban Transportation Planning
   - 16-545 Public Transit Planning and Design
   - 16-547 Airport Planning and Design

3. Courses in the College of Management
   - 66-672 Operations Management
   - 66-772 Operations Planning and Control

66-774 Industrial Relations
66-622 Marketing
66-701 Starting a New Venture
66-731 Financial Management
66-783 International Business Relations
66-651 Human Resources Management

4. Courses in the College of Pure and Applied Science
   92-591 Statistical Modeling and Data Analysis
   92-587 Mathematical Statistics I
   92-588 Mathematical Statistics II
   92-582 Regression and Time Series
   92-584 Stochastic Processes
   92-585 Queueing Theory

Prerequisites for the Interdepartmental Program
Doctoral candidates taking the interdepartmental courses will be assumed to meet the following prerequisites:

- excellent oral and written communication skills
- a working knowledge of the basic concepts in probability and statistics
- a working knowledge of microeconomics and engineering economics

It is assumed that the student has acquired this knowledge through courses at the undergraduate or graduate level. A student who cannot demonstrate credit in appropriate courses or who is found lacking in any of these areas will be required to take remedial courses. No credit for remedial courses is given within the doctoral program.

Course Descriptions

25-510 A Systems Approach to Maintenance (3-0)3
Analysis of maintenance as an integral part of an enterprise. The purpose of maintenance; classical models; the role of information; dynamic maintenance - a systems approach; development of maintenance programs; management of maintenance; maintenance in various industries; project.

25-530 Engineering Systems Analysis (3-0)3
Introduction to methods of operations research, management science and economic analysis used in the design, planning and managing of engineering systems. Main topics covered are: the systems approach; optimization methods; network models; mathematical programming; organizational networks (cpm); decision analysis; economic criteria in systems planning; simulation methods.

25-543 Transportation Systems Analysis (3-0)3
This course presents a framework for the analysis of a wide range of multimodal transportation problems. The basic paradigm: demand, supply and equilibrium. Models of transportation demand and their relation to the socioeconomic system. Modeling transportation technologies and performance functions. The network equilibrium process. Prediction of impacts and searching for optimal strategies. Economic, social, environmental and political consequences of transportation decisions.

25-610 Doctoral Seminar **(1-0)1**
This seminar provides a forum for all elements of the interdepartmental program and exposes the students to leaders in engineering and other relevant fields. Each student is required to prepare a formal paper on a subject covered by one of the external speakers.

25-620 Accounting **(3-0)3**
The course provides and understanding of the internal financial mechanisms of a corporation. The following subject areas are covered: basic accounting principles; development and analysis of the balance sheet and profit and loss statements; legal requirements; a guide to the accounting profession and to further readings.

26-530 Law and Ethics in Engineering **(3-0)3**
This course provides an understanding of legal and ethical norms affecting the practice of engineering and the leadership of a technical organization. The following subject areas are covered: contracts; liability; incorporation; patent law; ethics of engineering; ethics of business; a guide to legal services and to further study.

25-640 Organizational Behavior **(3-0)3**
This course provides an understanding of interactions between people and of leadership of people. The following subjects are covered: models of human behavior; motivation; leadership; decision making; management conflict and change; designing organization structures and control systems; managing work groups and project teams; motivation; a guide to the field and further study.

25-650 Philosophy of Engineering **(3-0)3**
This course consists of an intensive philosophical reflection upon the epistemological, ethical, aesthetic, and metaphysical premises, dimensions, and implications of engineering as the process by which the human race invents, applies, and develops tools, instruments, and machines of all sorts and thereby transforms materials and energy-sources to its own uses.

25-660 Large System Design - Course **(3-0)3**
Development of skills for leading large projects from conceptualization to implementation. Analysis of complex situations; creative design and aesthetics; organization of design and development work (with cases); management of design and development work (with cases).

25-661 Large System Design - Project **(0-3)3**
Optional second (and further) terms following the course, large system design. Group projects on a real problem. Emphasis on conscientious project management.

25-670 Quantitative Methods of Operations Research - Probabilistic Models **(3-0)3**
Prerequisites: Mathematics courses of undergraduate and graduate programs; prerequisites for interdepartmental program; Doctor of Engineering candidacy or similar level of maturity.
Overview of theory and application of probabilistic models of operations research. Probability theory; statistical inference; stochastic processes and queueing theory; simulation. Introduction to and use of available software; guide to further work (self study). Format: review of theory and literature; examples of applications; use of computer systems (assignments).

25-675 Quantitative Methods of Operations Research - Deterministic Models **(3-0)3**
Prerequisites: Mathematics courses of undergraduate and graduate programs; prerequisites for interdepartmental program; Doctor of Engineering candidacy or similar level of maturity.
Overview over theory and application of deterministic models of operations research. Linear programming; integer programming; network analysis; dynamic programming; nonlinear programming. Introduction to and use of available software; guide to further work (self study). Format: review of theory and literature; examples of applications; use of computer systems (assignments).

COLLEGE OF HEALTH PROFESSIONS

DEAN: ELEANOR FORSLEY SHALHOUP, *Professor;* B.S., St. Anselm's College; M.S., C.A.G.S., Ed.D., Boston University.

ASSISTANT DEAN: SUSAN WOZENSKI; A.B., Mt. Holyoke; M.P.H., University of Michigan; J.D., University of Connecticut.

HEALTH SERVICES ADMINISTRATION

DEPARTMENT CHAIRPERSON: KAREN M. LORENTZEN; B.S., Adelphi University; M.S., St. John's University,; Ed.D., Boston University.

GRADUATE COORDINATOR: BEVERLY J. VOLICER; A.B., University of Iowa; M.A., M.P.H., Ph.D., University of Michigan.

Faculty:

Frank Gallo, *Assistant Professor;* B.A., M.Ed., Hofstra University; M.S.W., Ph.D., Boston University (Interim).
James Hester, *Assistant Professor;* B.S., M.S., Ph.D., M.I.T.
Linda Roemer, *Assistant Professor;* A.B., Stanford University; M.A., Ph.D., Tufts University (On Leave).

Master of Science Degree Program in Health Services Administration

Philosophy of the Department of Health

The faculty of the Department of Health believes that each individual is a unique rational human being who must have the opportunity to interact effectively within a changing environment. Individuals possess innate rights, one of which is the attainment of the goal of optimal health. Society, through its community and educational institutions, has a responsibility to make available for its citizens the methods and means for achieving the goals for an optimal level of health. To this end the Department of Health is committed to prepare professional practitioners who, from their own health practice discipline, assist the individual, the family, the group and the community to achieve as high a level of health as possible.

Program Intent

The goal of the graduate program in Health Services Administration is to provide health services administrators with the specialized knowledge and skills necessary to administer the delivery of high quality and cost effective health services. Computer skills necessary for modern health care management are taught and used throughout the curriculum. The program is designed to accommodate individuals already employed in the health care field who wish to further their professional training, and for college graduates preparing to enter the field. Course requirements may be completed on either a full-time or part-time basis.

Admission Requirements

Baccalaureate degree from an accredited institution. An undergraduate scholastic average of 3.0 or better. Three letters of recommendation pertaining to academic ability and professional performance. Personal interviews if requested by departmental faculty. Acceptable score on the Graduate Management Admission Tests (GMAT) or Graduate Record Examination (GRE). Satisfactory completion of the following prerequisites: Statistics and Accounting. Applicants who do not meet all of the above requirements may be admitted on a provisional basis, on recommendation of the graduate faculty.

Program Requirements

1. Credits

   Forty-eight credit hours of course work will be required of all students enrolled in the program. There are no formal language requirements or comprehensive examination requirements. A project or a thesis is required for graduation.

2. Program of Studies

   The Master of Science in Health Services Administration consists of 48 credits:

9 Core Courses	27
4 Electives (at least one elective must be taken outside the department)	12
Internship (students with substantial work experience in the health care field may take 3 credits of internship plus one additional elective)	6
Project or Thesis	3
	48

The core courses include the following and must be taken by each student in the program:

32-602 Organizational Behavior in Health Care Services
32-604 Epidemiology
32-606 Quantitative Methods for Health Services
32-607 Evolution and Impact of Computers in Health Care
32-611 Health Care Finance
32-612 Operations Analysis and Control
32-613 Research Methods in Planning and Evaluation
32-614 Human Resource Management in Health Services Organizations
32-616 Legal Issues in Health Services Administration

All students must also complete the following courses:

32-617 Internship and Seminar
32-619 Project or Thesis

The following departmental electives can be used to develop an individualized specialization according to the interests of the student:

32-621 Management Information Systems
32-622 Implementation and Organizational Impact of Health Care Information Systems
32-625 Health Policy
32-626 Program Management and Evaluation
32-627 Planning and Marketing for Health Care Services

Health Services Administration Program Expected Outcomes

Each student upon completion of the program is expected to:

A. Integrate knowledge from the fields of health services and health systems, management, health, and the behavioral sciences to identify analyze, and address problems.
B. Apply theory to the formation of concepts in the administration of health care.
C. Demonstrate specialized administrative competencies including advanced skills in the functions of planning, organizing, controlling and evaluating health care.
D. Analyze legal, fiscal, regulatory and environmental factors influencing health care and its delivery.
E. Demonstrate the ability to make effective administrative decisions.
F. Communicate effectively.
G. Educate providers and consumers of health care services in effective and efficient use of the system.
H. Collaborate with health practitioners and consumers to promote the development of high quality, cost-effective delivery.
I. Demonstrate knowledge of research methodology.
J. Utilize research to improve practice and expand knowledge in Health Services Administration.
K. Show evidence of continuing personal and professional growth including emerging leadership qualities.
L. Demonstrate basic competency in the financing of health care delivery and the application of computers to health care administration.

Program of Studies

1st semester

32-602 Organizational Behavior Health Care Services
32-604 Epidemiology
32-607 Evolution and Impact of Computers in Health Care
XX-XXX Elective

2nd Semester

32-606 Quantitative Methods for Health Services
32-611 Health Care Finance
32-614 Human Resource Management in Health Services Organizations
XX-XXX Elective

3rd Semester

32-612 Operations Analysis and Control
32-613 Research Methods in Planning & Evaluation

4th Semester

32-616 Legal Issues in Health Services Administration
32-619 Project/Thesis

32-617	Internship and Seminar	XX-XXX Elective
		XX-XXX Elective

All courses listed for the first and second semesters should be completed before third and fourth semester requirements are taken. Course offerings are scheduled according to projected enrollment.

Course Descriptions

32-602 Organizational Behavior in Health Care Organizations **(3-0)3**
The application of social science theory to health care organizations. Provides an overview of health care organizations, including alternative delivery systems. Examines variables which influence organizational performance. Roles of key actors are identified. Structural problems are discussed. Students are given practice in utilizing what they have learned to solve organizational problems.

32-604 Epidemiology **(3-0)3**
Introduction to an understanding of the etiology of disease as derived from population data. Focus on the integration of biostatistical and biological elements into analysis of the causes and distribution of health problems. Particular emphasis on applications of epidemiological reasoning to problems in health services administration.

32-606 Quantitative Methods for Health Services **(3-0)3**
Prerequisites: An elementary statistics course and 32-607.
Provides a basic understanding of the use of bivariate and multivariate statistical techniques in the analysis of health data. Focus on choice of appropriate analytic techniques and interpretation of results, using statistical software as a mechanism for data analysis.

32-607 Evolution and Impact of Computers in Health Care **(3-0)3**
Overview of key components of information systems using examples drawn from health care settings. Evolution of HCIS's with emphasis on factors which have limited their adoption. Review of main trends in information technology and potential impact on health care institutions. Project required.

32-611 Health Care Finance **(3-0)3**
Overview of major factors affecting the increase in health care costs and the evolution of state and national policies providing the context for health care financial management. Review of major approaches to cost control including insurance benefit design, regulation and competition.

32-612 Operations Analysis and Control **(3-0)3**
Prerequisites: An elementary accounting course and 32-606.
Fundamentals of the analysis and control of internal operations of health care institutions. Emphasizes quantitative methods and the use of standard micro-computer software, e.g., spreadsheet programs. Includes an introduction to simple stochastic and probabilistic operations research methods.

32-613 Research Methods in Planning and Evaluation **(3-0)3**
Development of knowledge and skills useful for research in health related disciplines. Topics include development of a researchable problem, study design, measurement, data collection, analysis and interpretation of findings. Focus on application of the research process to program planning and evaluation. Each student will develop a research proposal.

32-614 Human Resource Management in Health Service Organizations **(3-0)3**
Prerequisite: 32-602
Emphasis is on the policies, methods and techniques used in human resource management and relations as a management function. The capacity to analyze problems, select the most effective means of dealing with them, and plan appropriate courses of action is developed. Attention is given to such areas as motivation, evaluation, and conflict resolution.

32-616 Legal Issues in Health Services Administration **(3-0)3**
Overview of legislative and regulatory processes at federal and state levels and consideration of the legal basis for government support and regulation of health care services. Detailed study of business and health law of importance to the health services administrator including contracts, labor law, negligence, malpractice, and patients' rights.

32-617 Internship and Seminar **(0-9)3**
Provides an opportunity for the student to work in administration in a health care organization under the supervision of a qualified preceptor. The student will take responsibility for a task, assignment or project within the organization. Periodic seminars with faculty integrate this experience with academic training. Individualized placement decisions are made by faculty on the basis of student interests, needs and abilities.

32-619 Project or Thesis **(3-0)3**
Each student is required to complete a project under the supervision of a faculty member. The project is intended to integrate the concepts and skills learned in previous courses, should be original and make a contribution to the field. Students may choose to do a thesis that must be done in accordance with the requirements of the Graduate School.

32-621 Management Information Systems **(3-0)3**
Overview of major types of M.I.S. applications in health care settings. Review of components of an M.I.S. and recent trends in the software tools available for creating them. Summary of current issues in design of control systems both for administration of institutions and for managing patterns of patient care.

32-622 Implementation and Organizational Impact of Health Care Information Systems **(3-0)3**
Presents the fundamentals of project management and the implementation of an information system in a health care setting with particular attention to the relative roles of users and data processing staff. Considers the organizational consequences of changes in information flow and availability of outline approaches to assessing the effectiveness of the system.

32-625 Health Policy **(3-0)3**
Provides students with a framework for policy analysis and examines major strands of U.S. health policy. Detailed consideration and discussion of the relationship of national policy to the planning, implementation and funding of health care services.

32-626 Program Management and Evaluation **(3-0)3**
Fundamentals of management of ongoing programs and techniques of introducing programmatic changes in an operational setting. Management functions are examined with special emphasis on coordination and control. Program evaluation strategies are discussed with special reference to political and social considerations.

32-627 Planning and Marketing for Health Care Services **(3-0)3**
Examines the history, principles and methodology of population-based and strategic planning. Identification of resources available to the planner and exploration of the role of the administrator in planning. Study of marketing of health care services and of the relationship between planning and marketing.

DEPARTMENT OF NURSING

DEPARTMENT CHAIRPERSON: MAY FUTRELL, *Professor;* B.S., M.A., Columbia University; Certificate, University of Southern California; Ph.D., Brandeis University.

GRADUATE COORDINATOR: ELIZABETH DALY, *Assistant Professor;* B.S., Boston College; M.S., D.N.Sc., Boston University.

Faculty

Clarice Andrews, *Assistant Professor;* B.S., Simmons College; M.S., Boston University.
Nina M. Coppens, *Assistant Professor;* B.S., M.S., Northern Illinois University; Ph.D., University of New Hampshire.
Marian D. Dubrule, *Associate Professor;* B.S., Iowa State University; M.N., Yale University; M.Ed., M.S., Ed.D., Boston University.
Susan Houde, *Instructor; B.S.,* Lowell State College; M.S., University of Lowell.
Joan Lewis, *Associate Professor;* B.S., Ed.M., Boston College; Ed.D., Boston University.
Diane Feeney Mahoney, *Instructor;* B.S., Boston College; M.S., University of Lowell.
Karen Devereaux Melillo, *Instructor;* B.S., Salem State College; M.S., University of Lowell.
Susan Murphy, *Instructor;* B.S., Worcestor State College; M.S., Boston College.
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Janice Stecchi, *Professor;* B.S., Boston College; M.Ed., Salem State College; M.S., Ed.D., Boston University.
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Naomi Zack, *Instructor;* B.S., Northeaster University; M.S., University of Lowell.

Master of Science Degree

Philosophy of the Department of Nursing

The philosophy of the Department of Nursing supports the undergraduate and graduate programs within the overall philosophy of the College of Health Professions and the University of Lowell. The faculty of the Department of Nursing accepts the following statements as a reflection of their beliefs.

Man is a unique, sentient and rational being endowed with individual qualities, but has, in common with other humans, basic needs for respect, worth, and recognition of personal dignity. Man is perceived as continually adapting by developing and interacting, individually or in groups, purposively with a changing multidimensional environment. Dynamic relationships with the environment both enable and limit individual development and health. Man has the right and ability to make choices and establish goals which determine his future. Access to opportunities for growth and possible change is influenced by individual differences and culturally-defined values and beliefs.

Health is a dynamic state of physiological, psychological, social and spiritual well-being and not merely the absence of disease. Man manifests health on a wellness continuum and has the potential for multidimendional movement. Health care is a right, and man's option to choose participation in the process of health care delivery must be respected.

Nursing, as an academic and practice oriented discipline, has the responsibility to develop and refine its knowledge base. Through continuing scientific inquiry and analysis of existing theories, new or modified conceptions and relationships can be operationalized in professional nursing practice. Practice is carried out through application of the nursing process and actions that are scientific, rational, deliberate, and humanistic.

The faculty believes that education is a self-actualizing, creative lifetime endeavor which involves values clarification, progressive systematic inquiry, critical analysis and judgement. Baccalaureate nursing education incorporates liberal education with generalized preparation in professional nursing. The professional nurse is prepared at the baccalaureate level to function in collaborative relationships with other health professionals in a variety of health care settings to deal with diversified health concerns of various clients.

The faculty believes that graduate education in nursing is built upon the development and integration of professional knowledge, attitudes and skills acquired for the first professional degree. Graduate education is based on research and scholarship and includes conceptual formulations of professionalism, systematic inquiry and leadership. In graduate education, the University's commitment to discover, integrate, interpret, and transmit theories emerging in nursing and other fields, to test models designed to deliver health care and services consonant with the needs of society and the Commonwealth, and to plan to meet future needs of the practice field is emphasized. Students pursuing the masters degree with a major in nursing should be given the opportunity to study the economic social, political, legal, and technological forces that will affect their roles as leaders. Within these constructs, mastery in one area of specialization in nursing is emphasized. Further professional development and self-actualization occur through continuing education and doctoral study.

The faculty also recognizes that each student is unique and brings to the educational environment a variety of life experiences. Individual interests and goals are recognized as an important component of the educational process. Faculty assumes responsibility for the overall structuring of the education which allows for the discovery, transmission and integration of knowledge and the acquisition of skills to achieve personal and professional goals. Teacher and learner participate in the educational process through planning educationally sound and growth-promoting experience and sharing knowledge. Support of the individual's growth and self-evaluation during the educational process enables the student to develop his/her own professional philosophy which will be refined throughout his/her career.

Purpose

The major purpose of the Master of Science Program is to prepare leaders who advance the practice of nursing through the application and testing of specialized knowledge and skills that promote the health of individuals and groups.

The second purpose is to provide a basis for doctoral education.

Admission Requirements
Applicants must have a baccalaureate degree with a major in nursing from an accredited program; an undergraduate scholastic average of B or better; an introductory course in descriptive and inferential statistics and official scores on the Graduate Record Examination. He/she must be licensed to practice nursing in the Commonwealth of Massachusetts; have a personal interview and must have three letters of recommendation pertaining to academic ability and professional competency.

Degree Requirements
Credits
A minimum of 42 credit hours of course work will be required of all students. There are no formal language or comprehensive examination requirements. A project which will consist of a scholarly investigation or a thesis is required for graduation.

Administration of Nursing Services
Expected Outcomes
Each student upon completion of the Administration of Nursing Services program will be expected to:

1. Possess a body of knowledge basic to the administration of nursing services.
2. Synthesize knowledge from nursing and relevant disciplines for the purpose of analyzing nursing practice and proposing solutions for identified problems.
3. Evaluate and apply theories of management in the health care setting.
4. Evaluate organizational behavior and use appropriate means to initiate change.
5. Demonstrate skills in the areas of leadership, decision- making, budget preparation, communication and time management.
6. Assume a nursing leadership role in health care delivery through collaboration, consultation, advocacy and innovation.
7. Use the research process to advance the theory and practice of administration of nursing services.
8. Demonstrate nursing management competencies in the functions of planning, organizing, controlling and evaluating nursing services.
9. Collaborate with members of other disciplines and with consumers in matters of health care and social policy legislation.
10. Assume responsibility for ongoing personal and professional growth.

Curriculum
The program is four semesters in length. The curriculum is divided into three interrelated segments: cognates, nursing theory, and practicum experiences in administration. The sequential order of the curriculum is planned to provide the student with knowledge and skills necessary for leadership in nursing-service settings.

Program of Studies

Semester I

33-600	Theoretical Foundations for Advanced Nursing Practice	3
33-680	Nursing Administration I	3
32-602	Organizational Behavior in Health Care Services	3
60-601	Financial Accounting	3
	Total	12

Semester II

33-553	Research Design and Methodology	3
33-681	Nursing Administration II	3
33-682	Nursing Administration II Practicum	1
32-611	Health Care Finance	3
	Total	10

Semester III

33-683	Nursing Administration III	3
33-684	Nursing Administration III Practicum	1
32-614	Human Resource Management in Health Service Organizations	3
33-615	Nursing Research - Independent Study	3
	Total	10

Semester IV

32-607	Evolution and Impact of Computers in Health Care	3
33-685	Nursing Administration IV	4
	Elective	3
	Total	10

Summary of Subject Area Concentration

Scientific Basis of Nursing		9
Theory	3	
Research	6	
Nursing Speciality		15
Cognates		15
Finance	6	
Computer	3	
Management	6	
Elective		3
	Total	42

Gerontological Nursing
Expected Outcomes

Each student upon completion of the program of study will be expected to:

1. Communicate a philosophy of gerontological nursing through practice.
2. Possess a body of knowledge basic to the practice of gerontological nursing.
3. Synthesize knowledge from gerontology, the behavioral sciences and natural sciences for the purpose of developing concepts and constructs for gerontological nursing practice.
4. Evaluate and apply theories in the application of nursing process to the care of the aged and aging population.
5. Demonstrate expertise in the areas of history-taking, health assessment and health care management of well and sick elderly.
6. Assume a nursing leadership role that includes innovation, consultation, advocacy, accountability and responsibility for improvement of health services to the aged.
7. Utilize research methodology to advance the practice of gerontological nursing.
8. Propose alternative solutions to problems in the delivery of health care to the elderly as a result of investigatory studies.
9. Evaluate effectiveness of community services designed to meet the needs of the aged and aging population and use appropriate resources to initiate change.
10. Collaborate with consumers and other health disciplines in matters of health care and social policy legislation.
11. Assume responsibility for ongoing personal and professional growth.

Curriculum

The program is four semesters in length. The curriculum is divided into three interrelated segments: cognates, nursing theory, and clinical experience. The sequential order of the curriculum is planned to provide the student with knowledge and skills necessary for leadership as a gerontological nurse practitioner.

Program of Studies

Semester I		
30-550	Biological Aspects of Aging - Birth to Death - and Pathophysiology	3
33-600	Theoretical Foundations for Advanced Nursing Practice	3
33-651	Nurse Practitioner Role - Theory and Practice	3
	Elective	3
	Total	12
Semester II		
33-610	Gerontological Nursing I	4
33-613	Practicum in Gerontological Nursing I	3
33-553	Research Design and Methodology	3
	Total	10
Semester III		
33-611	Gerontological Nursing II	4
33-614	Practicum in Gerontological Nursing II	3
47-551	Psychosocial Aspects of Aging	3
	Total	10
Semester IV		
33-612	Gerontological Nursing III	4
33-615	Nursing Research - Independent Study	3
	Elective	3
	Total	10

Summary of Subject Area Concentration

Scientific Basis of Nursing		9
Theory	3	
Research	6	
Nursing Specialty		21
Cognates		6
Biological	3	
Psychosocial	3	
Electives		6
		42

Family and Community Health Nursing
Expected Outcomes
Each student upon completion of the Program of Study will be expected to:

1. Communicate a philosophy of family and community health nursing through practice.
2. Possess a body of knowledge basic to the practice of family and community health nursing.
3. Synthesize knowledge from nursing, community health, and the behavioral and natural sciences for the purpose of developing concepts and constructs for family and community health nursing practice.
4. Evaluate and apply theories in the application of nursing process to the care of either the family and its members, or to young, middle, and aged adults in the community.
5. Demonstrate expertise in the areas of history-taking, health assessment and health care management of well and sick clients.
6. Assume a nursing leadership role that includes innovation, consultation, advocacy, accountability and responsibility for improvement of health services to the client and the community.
7. Utilize research methodology to advance the practice of family and community health nursing.
8. Propose alternative solutions to problems in the delivery of health care to the client and community as a result of investigatory studies.
9. Evaluate effectiveness of community services designed to meet the needs of the client and use appropriate resources to initiate change.
10. Collaborate with consumers and other health disciplines in matters of health care and social policy legislation.
11. Assume responsibility for ongoing personal and professional growth.

Curriculum
The program is four semesters in length. The curriculum is divided into three interrelated segments: cognates, nursing theory, and clinical experience. The sequential order of the curriculum is planned to provide the student with knowledge and skills necessary for leadership as a family nurse practitioner.

Program of Studies
Family Nurse Practitioner
Semester I

33-600	Theoretical Foundations for Advanced Nursing Practice	3
30-550	Biological Aspects of Aging - Birth to Death - and Pathophysiology	3
33-651	Nurse Practitioner Role - Theory and Practice	3
	Elective	3
	Total	12

Semester II

33-660	Family and Community Nursing Health I	4
33-663	Family and Community Nursing Health I Practicum	3
33-553	Research Design and Methodology	3
	Total	10

Semester III

33-661	Family and Community Nursing Health II	4
33-664	Family and Community Nursing Health II Practicum	3
47-504	The Family System	3
	Total	10

Semester IV

33-662	Family and Community Nursing Health III	4
33-615	Nursing Research - Independent Study	3
	Elective	3
	Total	10

Summary of Subject Area Concentration

Scientific Basis of Nursing		9
Theory	3	
Research	6	
Nursing Specialty		21
Cognates		
	3	6
Biological	3	
Psychosocial	3	
Electives		6
	Total	42

Course Descriptions

30-550 Biological Aspects of Aging - Birth to Death- and Pathophysiology **(3-0)3**

Study of the biological aging process and its effect on the various physiological parameters of wellness. Systems theory as it applies to Man, serves to unify conceptual approaches used to examine the physiological steady state and the disruptions that result in pathophysiological mechanisms and manifestations of disease states. The physiologic resources in terms of defensive, compensatory, and adaptive responses to pathophysiologic processes are examined.

33-553 Research Design and Methodology **(3-0)3**

Study of the research process and the application of appropriate designs and methodologies in the investigation of health care problems.

33-600 Theoretical Foundations for Advanced Nursing Practice **(3-0)3**

Examination of the development and formulation of nursing theory through systematic exploration of concepts and the process of theory building. The student will analyze and evaluate nursing theory from the viewpoint of new knowledge. Congruency between significant nursing theories and nursing practice will be identified.

33-615 Nursing Research - Independent Study **(3-0)3**

Application of research design and methodology culminating in the completion of a masters project or thesis under the guidance and supervision of the faculty.

33-651 Nurse Practitioner Role - Theory and Practicee **(2-4)3**

Analysis and conceptualization of the nurse practitioner role in health care delivery systems.

Administration

33-680 Nursing Administration I **(3-0)3**

A study of the philosophical, social and scientific foundations of nursing's involvement in management of health care services. An analysis of major events that have contributed to the evolution of contemporary nursing services. Literature from nursing and related fields will be examined as a basis for analyzing and developing conceptual models for the administration of nursing services.

33-681 Nursing Administration II **(3-0)3**

Examination of existing models for delivery of nursing services in a variety of organizational structures. Evaluation of selected management theory to determine its applicability to nursing management issues and to assess its relevance for ongoing development of nursing administration theory. Building on the previous semester, emphasis in this course is on the refinement of conceptual models for the practice of nursing adminstration.

33-682 Nursing Administration II Practicum **(3-0)3**

Observation and experience in a health care setting. Analysis of organizaional behavior based on nursing and management theories.

33-683 Nursing Administration III **(3-0)3**

The focus of the course is on the use of theory to explain the role and functions of an administrator of nursing services. Emphasis is placed on systematic investigation of nursing situations to discriminate between clinical problems and management issues. Conceptual models developed in Nursing Administration I and II are used to plan and evaluate strategies for change. Concepts, functions, basic to nursing administration, of decision-making, budget preparation, time management, advocacy, quality assurance and ethical/legal issues are included.

33-684 Nursing Administration III Practicum **(0-4)1**

Experience in a nursing care setting to analyze selected nurse management functions. Nursing organizational patterns and functional roles are studied relative to institutional policies. Focus on problem-solving in nursing management using the conceptual models developed in previous courses.

33-685 Nursing Administration IV **(1-12)4**

A practicum in administration of nursing services. This course provides students with the opportunity to synthesize the knowledge and skills from nursing and cognate courses into the leadership role of a nursing service manager. Students meet in a weekly seminar to critically evaluate the role of the contemporary nurse manager.

Gerontological Nursing

33-610 Gerontological Nursing I **(4-0)4**

Focus will be on theories essential to understanding the needs of the aging population. Particular attention will be paid to the relationship of these theories to the well being of the aged individual. The student explores in depth the organization and practices of health care delivery systems available to the elderly in a selected community.

33-611 Gerontological Nursing II **(4-0)4**
This course builds on knowledge and theories identified in courses in previous semesters. The focus of this course is on the restoration of wellness in the older adult with short and long-term health problems.

33-612 Gerontological Nursing III **(1-12)4**
This course focuses on an intense clinical experience to facilitate the synthesis and analysis of the nurse practitioner role in promoting wellness of elderly clients. Independent, collaborative leadership and advocacy aspects of the role are emphasized.

33-613 Practicum in Gerontological Nursing I **(0-12)3**
Under the supervision of nursing faculty the student applies theory to practice in a variety of primary care settings. The practicum allows students to apply health assessment skills for the purpose of determining levels of wellness and identifying health problems in aged clients.

33-614 Practicum in Gerontological Nursing II **(0-12)3**
This course focuses on a systematic approach to the nursing management of elderly clients. Biopsychosocial factors related to well being are analyzed for purposes of implementing health care strategies. Emphasis is placed on application of leadership and role theory to the gerontological nurse practitioner.

47-551 Psychosocial Aspects of Aging **(3-0)3**
Analysis of current social gerontological literature on theory and research pertaining to biological, psychological and sociological variables over the adult life span. Age changes in a situational context will be examined and discussed.

Family and Community Health Nursing

33-660 Family and Community Health Nursing I **(4-0)4**
The development of theoretical knowledge and skills for advanced nursing practice with children, young adults and their families in community or primary care settings. Family development, common childhood and young adult health problems and their management are examined. Community needs and resources influencing family health are also emphasized.

33-661 Family and Community Health Nursing II **(4-0)4**
The development of theoretical knowledge and skills for advanced nursing practice with childbearing women, middle-aged, and older adults and their families in community or primary care settings. Factors influencing the health of clients are examined. Nursing strategies are developed and evaluated.

33-662 Family and Community Health Nursing III **(1-12)4**
An intensive clinical experience to facilitate the synthesis and analysis of the Family/Community practitioner role in promoting wellness. Independent, collaborative leadership and advocacy aspects of the role are emphasized.

33-663 Family and Community Health Nursing Practicum I **(0-12)3**
The application and integration of theoretical knowledge obtained in Family and Community Health I. Advanced Nursing process concepts and clinical judgement skills are emphasized in promoting family and community wellness.

33-664 Family and Community Health Nursing Practicum II **(0-12)3**
Application and integration of theoretical knowledge acquired in Family and Community Health I and II. Emphasis is placed on the use of a systematic approach in testing and evaluating family and community health concepts and nursing intervention strategies.

47-504 The Family System **(3-0)3**
This course will focus on the psychological and interactional processes within the family and the interplay between the family and other social, ethnic, religious, and socio-economic systems in the community. Topics examined will be the marital contract, parental roles, changing family structures, sibling influences, racial and ethnic factors, and the interaction between family and community life.

DEAN: PATRICIA A. GOLER, *Professor;* A.B., Regis College; A.M., Ph.D., Boston College; L.L.D. (Hon.) Regis College; D.H.L. (Hon.) Emmanuel College.

ASSISTANT DEAN: RICHARD L. DERRY: B.A., Holy Cross College, M.A., Boston College.

DEPARTMENT OF CRIMINAL JUSTICE

DEPARTMENT CHAIRPERSON: JOSEPH W. LIPCHITZ, *Professor;* B.A., M.A., University of Massachusetts; Ph.D., Case Western University.

GRADUATE COORDINATOR: ALAN JAY LINCOLN, *Professor;* B.S., Michigan State University, M.S., M.A., Ph.D., University of Massachusetts.

Faculty:

Eva S. Buzawa, *Associate Professor;* B.A., University of Rochester; M.S., Ph.D., Michigan State University.
James M. Byrne, *Assistant Professor;* B.A., University of Massachusetts; M.A., Ph.D., Rutgers University.
June M. Gonsalves, *Assistant Professor;* B.A., Northeastern University; J.D., Northeastern University.
Renee Kasinsky, *Associate Professor;* B.A., M.A., Ph.D., University of California, Berkeley.

MASTER OF ARTS IN CRIMINAL JUSTICE (This program has not as yet been approved)

Program Objectives

The Master of Arts in Criminal Justice program recognizes the diverse needs of criminal justice professionals but focuses upon the body of material that will prove most useful to the students and to the Commonwealth. Three clusters of courses will be offered, and the students will become exposed to each. A) Technology & Research in Criminal Justice, B) Management and Planning in Criminal Justice, and C) Crime and the Community. The program is designed:

A. To meet the needs of the Commonwealth of Massachusetts for Criminal Justice graduates to fill positions in teaching, research, management, and leadership in criminal justice agencies.

B. To prepare students for leadership positions in the administration of criminal justice agencies at the local and federal levels as well as the private sector.

C. To assist students in applying theory and research to real-world problems in criminal justice.

D. To prepare students for conducting quality research on crime measurement, causation, impact, and the effect of state and local policies on crime.

E. To provide students with knowledge about methods of crime control in the public and private setting.

F. To provide students with a thorough knowledge of the development of the current issues in criminal justice and the relationship of criminal justice to other social and behavioral sciences.

G. To educate students in the application of computer technology to decision-making in the criminal justice system.

H. To prepare students to apply skills in research, technology, management and intervention to the unique needs of their communities.

Expected Academic/Professional/Occupational Results
It is anticipated that the program will serve predominately four types of students:

A. Those seeking a terminal masters degree as a prerequisite for entry into the criminal justice field.

B. Those currently in-service in the criminal justice system who seek to broaden their skills and obtain job-related knowledge and expertise.

C. Those currently in the criminal justice system seeking to specialize and work in some other area of the system.

D. Those currently in the system or pre-service who wish to obtain the training and expertise necessary to meet the growing need for teaching criminal justice at the community college level.

In addition, our program will meet the needs of students considering preparation for eventual doctoral work in criminal justice.

Program Design
1. ADMISSION STANDARDS AND CRITERIA
Applicants should have the ability to pursue graduate education as demonstrated by:

A. Graduation from an accredited four-year institution.

B. Minimum undergraduate grade point average of 2.6 with a 2.75 average in the major courses.

C. Acceptable scores on the Graduate Record Exam.

D. Three letters of reference from those familiar with the educational and/or professional performance of the applicant.

E. Two copies of a complete and official transcript from each undergraduate and graduate institution attended.

F. An interview which may be requested by the Graduate Admissions Committee. Interviews generally will be utilized when the student has difficulty meeting the criteria above due to unusual circumstances.

Admission status may be of three types:

A. Matriculated student. A fully accepted degree candidate who meets all criteria.

B. Provisional. From time to time a student may be granted provisional status. To become a fully matriculated student, the provisional student must receive at least a 3.00 GPA in nine hours of criminal justice graduate level courses in the program.

C. Non-degree. When space permits, qualified students will be allowed to enroll in selected courses. Subsequent application to the program will allow for transfer of no more than twelve credits of B or better into the program.

Degree Requirements
All students will complete a minimum of 36 credits for the M.A. degree. Included in the 36 credit requirement is a core course sequence of 15 credits. The core consists of:

Research Methods in Criminal Justice I
Research Methods in Criminal Justice II
Crime and Delinquency: Causes and Consequences
Seminar in Management and Planning
Seminar in Crime and the Community

Pre-service students also will complete an internship with an acceptable criminal justice agency. All students, in addition to the core courses, will successfully complete at least one additional course from the Management and Planning sequence, one additional course from the Crime and Community sequence, and one additional course from the Technology and Research sequence. All graduate courses will require a significant project related to the course material.

Thesis. Students selecting to undertake a thesis enroll in the Thesis Seminar (up to six credits). A thesis advisor will work closely with the student.

Non-Thesis Option. Students selecting the non-thesis option will be required to pass successfully a comprehensive examination in the specialty area of their choice. Note that two courses in lieu of Thesis Seminar will be necessary to meet the 36 credit requirement.

Each student is expected to maintain a 3.0 grade point average in all courses taken. The retention policy will be consistent with that of the Graduate School and College of Liberal Arts.

Sequential Outline of DegeeE Program

During the first year of full time study, students are expected to complete four of the five core courses. The decision to submit a thesis or to select the non-thesis option will be made before the end of the first academic year. The consideration of possible thesis topics will be made during the first year. During the second year of full time study, students will enroll in the thesis seminar if appropriate. Selected specialty courses will be taken during the second or subsequent years. For pre-service students, the internship will be completed during the second year as well.

Academic Work in Related Fields of Study Toward the Degree

With the approval of the academic advisor, students can select up to nine credits of graduate level courses in other programs at the University. Courses will be selected from Education, Computer Science, or Management. Two courses in Community-Social Psychology are currently cross-listed with Criminal Justice and may be applied as courses within the major: Community Dynamics: Intervention and Change, and Program Evaluation.

Evaluation of Student Progress

Students will be assigned an academic advisor when entering the program. Individual programs will be developed consistent with the student's needs and goals. Students will be required to maintain a 3.0 cumulative average. If a student should receive a grade of BC or C, the academic advisor will meet with the student to discuss methods of improving performance. No more than six credits of C or BC may be counted toward the degree. If a student should receive a second C or BC, there will be a review by the graduate committee for such actions as a warning, probation, or loss of degree candidacy. Such actions will be subject to the approval of the College Dean.

Any student whose credit load is less than full time will meet at least once a semester with his/her advisor to discuss and review progress toward the degree. All requirements for the degree must be completed within five years of the time the student was first admitted as a matriculated student.

Procedures for Thesis Option

The thesis will be under the direction of a mutually acceptable thesis advisor. The thesis will represent the student's ability to formulate, carry out, and present a significant research project. A "defense of thesis" will be conducted before a panel including the thesis advisor (chair), a committee

member chosen by the student and approved by the department, and a third member selected by the graduate coordinator.

Thesis topics generally will be selected during the second research course taken in the first year. The thesis proposal will be developed in conjunction with the thesis seminar and must be approved by the thesis advisor and graduate coordinator. An approved copy of the proposal will be filed with the graduate coordinator.

Course Descriptions

TECHNOLOGY AND RESEARCH IN CRIMINAL JUSTICE

44-590 Research Methods in Criminal Justice I (3-0)3
An introduction to the methods of criminal justice research, including research design, terminology, standard methodologies, and the use of elementary statistics.

44-591 Research Methods in Criminal Justice II (3-0)3
Specific practice in the definition, design and execution of a research project, and an analysis of the impact of contemporary criminal justice research on policy development. Computer applications will be examined.

44-592 Criminal Justice Information Systems (3-0)3
A comprehensive examination of the development, utilization and evaluation of (computer-based) information systems in criminal justice agencies. Focus on the development of management information systems.

44-593 Computer Crime and Security (3-0)3
Examination of the causes and consequences of computer crime. The focus is on the use of the computer for criminal purposes.

44-692 Computer Applications in Criminal Justice (3-0)3
Application of computer technology to decision-making in the criminal justice system. A variety of computer applications are presented including computer mapping, forecasting techniques, simulations and modeling.

44-530 Technology and the Law (3-0)3
The focus is on the response of the legal system to technological changes in science, engineering and medicine as they impact upon both the law and the criminal justice professional.

44-690 Quantitative Analysis (3-0)3
Focuses on the application of advanced statistical techniques to research problems. Advanced computing methods (using SPSS and SAS) are also introduced.

44-790 Thesis Seminar (3-0)3
For graduate students in the early stages of thesis planning, this seminar will focus on the mechanics and details of thesis work. In the second semester students will continue to research and prepare the thesis itself.

44-680 Special Topics in Technology and Research (3-0)3
Possible topics will include models of decision making, social indicators, comparative research in criminal justice, prediction methods, and advanced statistics for criminal justice.

CRIMINAL JUSTICE MANAGEMENT AND PLANNING

44-570 Seminar in Management and Planning (3-0)3
The structures, functions, and operations of criminal justice agencies, including police, adult and juvenile courts and corrections.

44-531 Law of Administrative Procedures (3-0)3
General principles of administrative law, labor law, application of principles, law enforcement policy making and implementation of constitutional safeguards. Examination of police unions and political activity.

44-511 Planning and Program Development (3-0)3
Examination of the techniques of planning and program development in criminal justice agencies. Introduction to the key steps in the planning process, and the program design.

44-572 Personnel Administration (3-0)3
Explores current controversies in areas of signficant change in personnel administration of criminal justice agencies. Includes collective bargaining, professionalism, motivation, training, productivity, and accountability.

44-573 Public Policy and the Criminal Justice System (3-0)3
Analysis of interrelationship of criminal justice system components and the political setting surrounding the formulation and administration of public policies for crime control.

44-550 Issues in Correction Administration (3-0)3
Specific analysis of the management of correctional institutions, including custody, classification, reception, programming, release, staffing, scheduling, collective bargaining, prisoners' rights, and other related issues.

44-696 Fieldwork in Criminal Justice (3-0)3
Assigned field work under the supervision of a member of the department. Normally taken in the second year, the practicum course is designed for pre-service students.

44-681 Special Topics in Management and Planning (3-0)3
Courses include decision theory, budgeting, new managerial perspectives, affirmative action, crime scene management and issues in court administration.

CRIME AND THE COMMUNITY

44-520 Seminar in Crime and the Community (3-0)3
Factors that affect both personal and property crime in different communities. The impact and control of crime will be examined from the perspective of the society, community, special groups, offenders and victims.

44-521 Crime and Delinquency: Causes and Consequences (3-0)3
An overview of the nature and scope of delinquency and crime problems; considers the assessment and measurement of delinquency and crime; and explores the relationship among theory, research and policy.

44-522 Victimology (3-0)3
An examination of the characteristics and life styles of crime victims and the impact of their victimization. The treatment of victims by the criminal justice system will be examined along with possible reforms in these approaches.

44-621 Crime and Crime Prevention in Public Places (3-0)3
Focus is on the examination of current theory and research on crimes in schools, libraries,

museums, mass transit, parks, and other public places. Crime prevention and security programs appropriate for these public places will be emphasized.

44-561 Minorities and the Criminal Justice System **(3-0)3**
Both social and legal consequences of racism and discrimination will be discussed as they pertain to minorities and the criminal justice system.

44-650 Corrections in the Community **(3-0)3**
The history and development of programs relating to community treatment of offenders; the philosophies and programs dealing with the rehabilitation and integration of the offender into society.

44-622 Family Violence: System Response
The causes and consequences of intrafamily violence will be examined. Topics will include child abuse and neglect, sexual abuse, spouse abuse, and abuse of the elderly. Alternative techniques for dealing with these problems will be stressed.

44-675 Community Relations for Criminal Justice Professionals
Research underlying the ideal of effective communication and persuasion. The application of communication theory to relevant situations. Preventing and dealing with potential crises.

44-635 Constitutional Rights in Criminal Procedure
An examination of constitutional rights through the most recent decisions. This includes an analysis of the 1st, 4th, 5th, 6th, 8th, 9th and 14th amendments (i.e., search and seizure, arrests, bail, juries, trials, cruel and unusual punishment, etc.).

44-533 Elite Deviance and White Collar Crime
Examines the systematic violation of the laws and ethics of business and politics. The structure of power and privilege in relation to both political and economic deviance.

44-682 Special Topics in Crime and the Community
Topics may include victim compensation, sexual offenders, crisis management, comparative studies of crime and crime prevention, women and crime and intensive supervision in probation and parole.

DEPARTMENT OF PSYCHOLOGY

DEPARTMENT CHAIRPERSON: RICHARD SIEGEL, *Associate Professor,* A.B., Harvard College; M.S., Yale University; Ph.D., Boston University.

GRADUATE COORDINATOR: CHARLES NIKITOPOULOS, *Assistant Professor;* A.B., Suffolk University; M.A., New School for Social Research; Ph.D., Boston College.

Faculty:

Joan B. Cannon, *Associate Professor;* B.A., St. Mary's College; Ed.M., Boston University; Ed.D., Clark University.
Jon Hellstedt, *Associate Professor;* A.B., Augustana College; M.Div., Yale University; Ph.D., Boston University.
Kathleen Hulbert, *Associate Professor;* A.B., Northwestern University; Ed.M., Boston University; C.A.G.S., University of New Hampshire; Ed.D., Boston University.
David Landrigan, *Associate Professor;* B.S., Tufts University; M.A., Ph.D., University of New Hampshire.

Charlotte Mandell, *Associate Professor;* B.A., Brooklyn College; M.A., Ph.D., Columbia University.
Anne Mulvey, *Associate Professor;* B.A., Barat College; Ph.D., City University of New York.
Ronald M. Pickett, *Associate Professor;* A.B., Dartmouth College; M.A., PhD., University of Michigan.
Allie Scruggs, *Professor;* B.S., Ed.M., Ed.D.,. Boston University.
Linda Silka, *Associate Professor;* B.S. Oklahoma State College; M.A., Ph.D., Kansas University.
Mary Roth Walsh, *Professor;* B.S., Mount Mary College; M.S., Cornell University; Ph.D., Boston University.

Master of Arts in Community Social Psychology

Philosophy and Objectives of the Program

Community social psychologists study relationships betweeen social and environmental forces and the psychological well being of people. They seek to understand how individuals and groups are affected by such social influences as employment and educational opportunity, organization and delivery of public services, and the structure and climate of the many social systems within which people live and work.

This master's level program in Community Social Psychology has two main objectives. The first is to provide its students with a rich and practical understanding of how the organizations in which people operate influence their well being, adjustment and growth. The second is to equip students to address human problems in a wide variety of social settings. These objectives are met through a balanced program of classroom study and practical field experience, with emphasis on skills-oriented courses in systems analysis, research methods and intervention techniques. Graduates will be prepared to assume professional roles in community organizations, in public institutions or in business and industry.

This program is appropriate for students from various academic and occupational backgrounds. It attracts recent undergraduates from such fields as Psychology, Sociology, Political Science, Health, and Education. For those already working, it can enhance the skills and career development of counselors, social workers, nurses, teachers, government workers, administrators, and mid-level managers in many public and private sector positions.

Admissions Requirements

The Community Social Psychology program at the University of Lowell is *designed for older and non-traditional students with experience in a variety of work and community settings* as well as for recent college graduates. The requirements for admission include the following:

1. An undergraduate average of "B" or better in the field of psychology or a related major. Students from other major fields are invited to apply but may be asked to complete some undergraduate requirements. All applicants should have completed a basic statistics or research methods course; students lacking this prerequisite may take the undergraduate course at the University.
2. Acceptable performance on the Graduate Record Examination Verbal and Quantitative Aptitude Section, or on the Miller's Analogy Test.

3. Three letters of recommendation related to the applicant's educational and professional qualifications.
4. A personal letter including a statement about the applicant's professional interests, educational and work qualifications, and future goals.
5. Prospective candidates may be requested to participate in an interview with members of the program's admissions committee.

Transfer Credit

Matriculated students in Community Social Psychology are allowed to transfer up to 10 credits of course work completed at other accredited universities provided that such courses are within the content area of community social psychology and do not involve credit for field experience or professional work. Such transfer credit is subject to the approval of the Student Affairs Committee and the Graduate School.

Part-time Study and Non-Degree Status

While the program in Community Social Psychology provides for full-time study, part-time students are encouraged to apply. In fact, the majority of students complete their program on a part-time basis. Courses are offered at late afternoon and evening hours to accommodate students who are employed.

Students not pursuing an advanced degree or who wish to begin their graduate study without first applying for matriculated status are invited to register as non-degree students for specific graduate courses on a space-available basis. Such students need meet only the first of the admissions requirements listed above. If a non-degree student later applies for acceptance into the Master's program, his/her application will be treated equally with those of other new applicants, though performance in graduate courses taken at the University may be used as an additional admissions criterion. Non-degree students accepted as matriculated students may transfer a maximum of 12 credits earned at the University toward the Master's degree.

Graduate Advisor

Each newly-matriculated student in the program will be assigned to an advisor from among the faculty of the graduate program. The student will meet with his/her advisor on a regular basis throughout the years of study to discuss course selections, planning for practicums, and the development of the thesis or project. Once a student selects a faculty supervisor for his/her thesis-project, this faculty member takes over as graduate academic advisor.

Degree Requirements

Credits

A total of 36 academic credits, at least 26 of which must be taken at the University of Lowell with a grade average of "B" or better, is required for the completion of the degree.

The 36 credits for the Master's degree are divided as follows:

Required	12 credits (47.501, 47.512, 47.520, and 47.525)
Electives	12 credits
Practicum	6 credits
Thesis or Project	6 credits
TOTAL	36 credits

Students are encouraged to participate actively in "tailoring" their program to achieve specific career and professional goals. This may be done through careful selection of coursework, independent study, practicum, and thesis or project experience. A limited number of approved courses taken outside the department may count as electives when these strengthen a student's identified area of interest.

Thesis or Project Requirement

The thesis or project is an original piece of work in the student's area of specialization. The thesis is a faculty supervised empirical study; the project is a faculty supervised change-oriented project. Each of these provides an opportunity for the student to demonstrate skills and knowledge acquired in the program and to make an original contribution to the field of Community Social Psychology. Students may register for 3, 6, or 9 credits in 47.751 while doing thesis or project work, but no more than 6 credits of 47.751 can be counted toward the 36 credit degree requirement. Students typically initiate the thesis/project after completion of 12 to 18 credits.

Research Opportunities

In addition to the basic curriculum, the Community Social Psychology program offers opportunities for students to be involved in interdisciplinary and collaborative community research projects working with faculty from the Psychology Department, from other social sciences and related disciplines, and with members of the community.

Course Descriptions

47-501 Applied Developmental Psychology **(3-0)3**

Provides a life span developmental perspective on individual and social adaptation and change. Examines appropriate theory and research, and illustrates the influences of environmental, social and cultural factors.

47-503 Applied Social Psychology **(3-0)3**

Introduces students to social psychology as an applied discipline. Covers such applied topics as attitude change, aggression, helping behavior, attribution, and interpersonal influence.

47-504 The Family System **(3-0)3**

Family processes and the interplay between the family and other social, cultural and socio-economic systems. Topics include parental roles, changing family structures, racial and ethnic factors, and interactions between family, work, and community.

47-511 Community and Social Aspects of Counseling (3-0)3
A systems analysis of the helping professions and methods of counseling in community and institutional settings (e.g., community mental health, employee assistance, and criminal justice). Also considers legal and ethical aspects of professional practice.

47-512 Applied Research Methods (3-0)3
Considers strengths and limitations of various experimental and non-experimental approaches to social psychological research. Develops skills for formulating research questions and translating them into practical study designs. Sensitivity to the ethics as well as the practicality and validity of research is emphasized.

47-513 Communication in Human Organizations (3-0)3
Examines factors in interpersonal and small group communication. Analyzes how information, ideas, and attitudes are transmitted between people and groups and studies techniques for improving communication in social systems.

47-520 Introduction to Community and Social Psychology (3-0)3
A survey of the field with an emphasis on its issues, methods, and applications. An analysis of how social and environmental forces affect individual and group well being, adjustment and change.

47-523 Women in the Community (3-0)3
An examination of women's roles in the home, community work place, in terms of psychological consequences, social structure, and options for change. Topics include: housework and child-care; violence against women; work stratification and women in non-traditional careers.

47-524 Ethnic and Racial Factors in the Community (3-0)3
Examines the multi-ethnic community and its effects on behavior, with major emphasis on conflict, prejudice and accomodation, as applied to a variety of social settings, including community institutional and industrial contexts.

47-525 Psychology of the Middle-Sized City: Lowell (3-0)3
Lowell serves as a model for examining the social issues and systems of mid-sized cities. The course considers how revitalization, neighborhoods, housing, education and industry affect quality of life.

47-551 Psychosocial Aspects of Maturity and Aging (3-0)3
Covers changes in behavior from adulthood to old age with emphasis on changes in personality, mental health, sensation and perception, intelligence and learning; and those individual, situational and cultural variables that contribute to successful aging.

47-611 Program Evaluation (3-0)3
Prerequisite: Completion of six graduate credits.
A skill-oriented approach that considers both formative and summative evaluation techniques. Emphasizes mastery of the technical aspects of the evaluation process.

47-621 Social System Dynamics: Intervention and Change (3-0)3
Prerequisite: Completion of six graduate credits.
Examines the structure and dynamics of mental health, educational, medical, industrial, and other systems with emphasis on strategies, theories, and ethics of social change.

47-622 Selected Topics in Community and Social Psychology (3-0)3
Prerequisite: Completion of six graduate credits.
Advanced topics in various areas of Community and Social Psychology. Offered regularly, reflecting special interests of the faculty and students, and may be repeated for credit.

Practicum

47-631 Practicum I **(1-9)3**

47-632 Practicum II **(1-9)3**

Provides supervised field experience in a setting appropriate to the student's area of specialization, plus on-campus class meetings. Nine to twelve hours of field work a week for two semesters are required. Students begin the Practicum upon completion of 12 and no more than 18 credits.

47-751 Graduate Research in Community-Social Psychology **3, 6, or 9**

Prerequisite: Approval of major advisor

For graduate students actively engaged in research or project work leading toward the submission of a written thesis or report. A program of supervised study will be arranged between the student and a faculty supervisor. This course may be repeated for credit, but only a total of 6 credits may be counted toward the Master's degree.

UNIVERSITY OF LOWELL

COLLEGE OF MANAGEMENT SCIENCE

MBA PROGRAM

DEAN: BENJAMIN CHINITZ, *Professor;* B.A., Yeshiva University; M.A., Brown University; Ph.D., Harvard University.

ASSISTANT DEAN: F. JOSEPH THOMAS, *Assistant Professor;* B.S., U.S. Naval Academy; M.M.S., Lowell Technological Institute; M.P.A., D.P.A., Nova University.

COORDINATOR: SANTO J. PULLARA, *Professor;* B.S., M.B.A., J.D., Ph.D., Syracuse University.

Faculty:

Russell P. Boisjoly, *Associate Professor;* B.S. University of Lowell; M.B.A., Boston University, D.B.A., Indiana University.
William J. Burke, *Professor;* B.A., University of Massachusetts; M.Ed., Boston State College; J.D., Suffolk Law School.
Harrison S. Campbell, *Associate Professor;* S.B., Massachusetts Institute of Technology; A.M., Ph.D., Columbia University.
Clairmont P. Carter, *Professor;* B.S., Pennsylvania State University; M.B.A., University of Akron; D.B.A., Kent State University.
Albert M. Cederlund, *Professor;* A.B., Clark University; M.S., Columbia University; Ph.D., Clark University.
Samuel Chesler, *Assistant Professor;* B.S., Boston University; M.B.A., Suffolk University.
Ellen Foster Curtis, *Associate Professor;* A.B., M.B.A., Ph.D., Indiana University.
Leslie M. Dawson, *Professor;* B.B.A., Iowa College; M.A., University of Toledo; Ph.D., Michigan State University.
George C. Dery, *Associate Professor;* A.B., Merrimack College; M.A., Boston College.
Gerald F. Downey, *Professor;* B.S., M.B.A., Northeastern University; M.A., Ph.D. Boston College.
Richard E. Ducharme, *Associate Professor;* B.S., Syracuse University; M.S., Air Force Institute of Technology (Ohio); Ph.D., Syracuse University.
Charles T. Feeney, *Professor;* B.S., Boston College; M.B.A., Northeastern University, C.P.A. (Massachusetts).
Stuart C. Freedman, *Associate Professor;* B.A., City University of New York; M.S., Ph.D., Cornell University.
Ralph Bowerman Gentile, *Assistant Professor;* A.B., Haverford College; M.A., Ph.D., University of Pennsylvania.
Robert H. Gregory, *Associate Professor;* B.S., M.B.A., Ph.D., University of Texas.
Brooke Hargreaves-Heald, *Assistant Professor;* B.A., Brandeis University, J.D., Northeastern University.
Brackston Hinchey, *Professor;* A.B., M.A., Ph.D., College of Business and Public Administration, University of Missouri.
Charles G. Hurst, Jr., *Associate Professor;* B.S., M.B.A. Ph.D., Wayne State University.
Bhagwat Jaiman, *Assistant Professor;* B.S., Delhi University; M.S., Indiana University.

Daniel J. Jones, *Assistant Professor;* B.A., B.S.M.E., University of Notre Dame; M.B.A., Harvard Business School; M.S., Bentley College.
Michael E. Jones, *Assistant Professor;* B.A., Denison University; M.B.A., University of Pennsylvania; J.D., University of Miami.
Timm L. Kainen, *Associate Professor;* B.A., Connecticut State University; M.A., University of Hartford; Ph.D., University of Massachusetts/Amherst.
M. Riaz Khan, *Professor;* B.S., M.S., University of Karachi; M.A., M.B.A., Ph.D., State University of New York (Buffalo).
Linda H. Kistler, *Professor;* B.S., M.S., Colorado State University; C.P.A. (Massachusetts).
Ramakrishnan S. Koundinya, *Associate Professor;* B.S., M.A., M.S., University of Madras, M.S., Carnegie Mellon University; Ph.D., New York University.
Anne M. Koen, *Assistant Professor;* B.S.B.A., University of Lowell; J.D., Suffolk University; L.L.M., Boston University; C.P.A. (Massachusetts).
David A. Lewis, *Assistant Professor;* B.S.I.E., Northwestern University; M.S.I.E., University of Texas/Arlington; Ph.D., University of Massachusetts.
Goang-Tzer Liaw, *Associate Professor;* B.A., National Taiwan University; M.A., University of Minnesota; Ph.D., University of Illinois (Urbana).
Thomas C. Macbeth, *Professor;* A.B., Cornell University; M.A., Ph.D., University of Southern California.
Stuart L. Mandell, *Commonwealth Professor;* B.A., Brooklyn College; M.B.A., Syracuse University.
Carol C. McDonough, *Professor;* B.A., Marymount Manhattan College; M.A., Ph.D., Boston College.
H. Lee Meadow, *Associate Professor;* B.S.B.A., Northeastern University; M.S.B.A., Ph.D., Virginia Polytechnic Institute.
James Philip Monahan, *Professor;* B.S., M.B.A., Boston College; Ph.M., Ph.D., Columbia University.
Jean Owen, *Assistant Professor;* B.A., Harvard University; Ph.D., Boston College.
Yash Puri, *Professor;* B.Sc., M. Sc., M.B.A., Delhi University; M.B.A., D.B.A., Indiana University (Bloomington).
Ralph A. Rieth, Jr., *Associate Professor;* A.B., Dartmouth College; M.B.A., Ph.D., University of Massachusetts.
Joseph R. Rocha, Jr., *Professor;* B.S., Northeastern University; M.B.A., New York University; J.D., Howard University; Ph.D., University of Iowa.
Ernesto Sanz, *Associate Professor;* B.A., Loyola University, (Spain); M.A., Kamakura Language College (Japan); M.A., Sophia University (Japan); Ph.D., Boston College.
Irwin A. Shapiro, *Professor;* B.S., Syracuse University; M.B.A., Indiana University; M.A., Ph.D., Clark University.
Balbir Sihag, *Associate Professor;* B.A., Dayanand College, India; M.A., Punjab University, India; Ph.D., Massachusetts Institute of Technology.
Paul E. Snoonian, *Associate Professor;* B.S., M.B.A., Northeastern University; M.A., Ph.D., Michigan State University.
Kathy S. Stevens, *Assistant Professor;* B.A. Brown University; M.S. Northeastern University; Ph.D., Purdue University.
Charles F. Thompson, *Associate Professor;* B.S.A., Bentley College; M.B.A., Northeastern University; C.P.A. (Massachusetts).
Bong M. Yang, *Assistant Professor;* B.A., Seoul National University; Ph.D., Pennsylvania State University.
Louis E. Yelle, *Professor;* B.S., Lowell Technological Institute; M.S., M.B.A., Northeastern University.

THE MASTER OF BUSINESS ADMINISTRATION (MBA) DEGREE PROGRAM

This program provides the student with access to first-rate graduate studies in business. Concentrations are available in the areas of accounting, finance, human resources management, marketing, operations management, and general management. The award of an MBA degree signifies that

the student has developed advanced skills in problem solving and decision making. The development of these skills in the University of Lowell program entails a searching examination of analytical tools, both theoretical and practical, and intensive training in their application through encounter with a wide range of topical cases. In addition, as part of their curriculum, students are encouraged to undertake independent investigation and scholarly reporting, although the MBA is not primarily a research degree.

Entrance Requirements
Admission to the MBA program is open to students with the baccalaureate degree. An aptitude for management decision-making and a demonstrated academic ability are the most important qualifications for admission. It is also recommended that applicants have an adequate mathematics background. An exposure to calculus for business administration is highly desirable. Without such exposure successful candidates will be required to do remedial work. Applicants should submit, along with their Graduate School application, a transcript of grades from their undergraduate institution, and a Graduate Management Admission Test (GMAT) score. Generally, to be eligible for admission a student should have attained an acceptable GMAT score and a good grade point average.

Part-Time Student Status
Many applicants have full-time jobs and family responsibilities; in an effort to ease their way, the program provides for part-time student status. Part-time students may take five years to complete the program. There is also a provision for extension of this time limit, provided the student initiates application for it, and can show good cause.

Student Status and Admission to MBA Courses
M.B.A. courses are open primarily to fully-matriculated degree candidates and provisionally admitted candidates, applicants who have been admitted on a probationary basis. However, graduate students at the University of Lowell and other colleges in the area (with the permission of these colleges) may register for courses on a space available basis with the permission of the graduate coordinator. Under this provision, graduate students in other programs at the University are permitted to take courses in the MBA program if the courses can be used as electives to meet degree requirements in their program. Holders of the MBA degree may enroll in any course for credit, provided they have the necessary prerequisites for courses selected.

Residency Requirement
To be recommended for the MBA degree, the student is required to complete a minimum of eleven courses (33 credits) at the University of Lowell, assuming nine courses (27 credits) have been successfully waived.

Waiver of Courses
A student may waive without substitution required core courses for previously completed, acceptable undergraduate or graduate courses. (SEE *GUIDELINES FOR WAIVER OF CORE COURSES - MBA*)[1] Other courses may be waived for previously completed, acceptable graduate courses.

After admission to the MBA program, students are expected to complete all courses at the University of Lowell, and only under special circumstances, and with prior approval, are students permitted to complete courses at other institutions.

Academic Grades, Probation and Suspension
Generally, the grading policy as stated in the Graduate School catalog is followed. Students who earn in excess of six credit hours with a passing grade below B will be placed on probation and subject to termination from the program. A student ordinarily is not allowed to repeat a course. Students who receive an F grade are automatically suspended from the program but may petition to the College's Graduate Administration Committee for reinstatement.

Curriculum Requirements
Sixty credit hours, twenty courses, are required for the MBA degree. The distribution of credits is: twenty-seven hours of core courses, six hours of advanced courses, twelve (accounting, fifteen) hours of concentration and fifteen (accounting, twelve) hours of electives.

Required Core Courses (9 courses - 27 hours):
60-601 Financial Accounting
64-601 Economics of the Firm
64-611 Quantitative Analysis
64-620 Public Finance and Monetary Policy
66-602 Information Systems for Management
66-622 Marketing
66-632 Business Financial Analysis
66-651 Organizational Behavior
66-672 Operations Management

Required Advanced Courses (2 courses - 6 hours):
66-673 Operations Research (Not required for accounting)
66-781 Business Policy

Area of Concentration Courses (4 courses - 12 hours, except accounting):

Accounting
60-612 Managerial Accounting
60-707 Intermediate Accounting I
60-708 Intermediate Accounting II
60-709 Advanced Accounting I
60-710 Theory of Financial Reporting

Finance
66-731 Financial Management
66-732 Financial Markets and Institutions
Finance Resource Elective
Finance Elective

Human Resource Management
66-652 Human Resource Management
66-774 Industrial Relations
Human Resource Elective
Human Resource Elective

Marketing
66-723 Marketing Analysis and Planning
66-724 Marketing Research
Marketing Elective
Marketing Elective

General Management
60-660 Law and Society
60-783 International Business
Elective
Elective

Elective Courses (5 courses - 15 hours). If an area of concentration is selected, no additional concentration courses may be included in this group. Not more than two (2) courses (6 hours) may be included from any area of concentration.

Courses typically meet weekly from 5 pm to 7:30 pm and 6 pm to 8:30 pm for fifteen weeks during the fall, from 5 pm to 7:55 pm and from 6 pm to 8:55 pm during the spring semester. During the summer sessions, courses meet twice a week for fifteen meetings; a special registration schedule will be issued by the College of Management Science.

GUIDELINES FOR WAIVER OF CORE COURSES - MBA[1]

Listed below are combinations of undergraduate courses that will generally qualifiy for waiver of MBA core courses, assuming "B" grades.

MBA CORE COURSE	UNDERGRADUATE COURSES FOR WAIVER
60-601 Fin. Acctg.	2 semesters - Prin. of Acctg.
64-601 Eco. of Firm	3 semesters - 1 Micro Eco. & 2 Macro Eco. & 1 Mgrl. Eco. (Or a major in economics)
64-611 Quant. Analysis	2 semesters - Bus. or Eco. statistics
64-620 Pub. Fin. & Mon. Pol.	1 semester - Money and Banking
66-602 Info. Sys. - Mgt.	1 semester - Mgt. Info. Systems
66-622 Marketing [3]	1 semester - basic Marketing (2) 1 semester - any advanced mktg. course

66-632 Bus. Fin. Analysis [3]	1 semester 1 semester	- basic Business Fin. and [2] - any advanced finance course (not money & banking)
66-651 Human Resource Mgt.	1 semester 1 semester	- Organization Behavior [4] - any advanced Hu. Res. [4] Mgt/ course
66-672 Operations Mgt. [3]	1 semester 1 semester	- basic Operations Mgt. & (2) - advanced operations mgt. course

[2] It is assumed these courses are completed at an accredited AACSB institution. If completed at non-AACSB institutions, an examination will be required.

[3] If only a basic undergraduate course has been completed in this subject area, a candidate may take an advanced MBA course in this subject and, if successfully completed, receive a waiver for the basic MBA course. Test is still required for non-AACSB courses.

[4] Course must have been taken at an AACSB accredited institution.

Courses of Study

60-601 Financial Accounting **(3-0)3**
This course provides an understanding of financial statements which are provided to users external to the economic enterprise. An examination of accounting procedures, financial accounting concepts, and the fundamentals of financial statement analysis and interpretation.

60-612 Managerial Accounting **(3-0)3**
Prerequisite: 60-601
The uses of accounting information by internal management. Product costing systems, cost allocation methods, budgeting and forecasting techniques, and alternative decision tools and methods.

60-631 Federal Income Taxes **(3-0)3**
Prerequisite: 60-601
The basic rules and regulations of the Internal Revenue Code as it affects individuals and business firms. The role of taxation in the business decision-making process; the tax effects of alternatives as to the types of organization, depreciation and inventory methods, mergers and acquisitions and other important topics.

60-660 Law and Society **(3-0)3**
The manager's role in understanding and determining the firm's relations with government and society. The tax and regulatory provisions of local, state, and federal agencies including such matters as anti-trust, mergers, and licensing. The social cost aspects of business ethics and problems in ecology.

60-707 Intermediate Accounting I (3-0)3
Prerequisite: 60-601
The generally accepted accounting principles relating to the preparation of financial statements. Students will engage in an in-depth study of accounting for and disclosing assets, including cash, temporary investment, receivables, inventories, plant and equipment, and intangible assets.

60-708 Intermediate Accounting II (3-0)3
Prerequisite: 60-707
Generally accepted accounting principles relating to the preparation of financial statements. An in-depth study of accounting for and disclosing share, pensions, leases, and income taxes.

60-709 Advanced Financial Accounting I (3-0)3
Prerequisite: 60-708
The theoretical and practical issues of accounting for large multinational businesses. Consolidations, mergers, and home office/branch accounting.

60-710 Advanced Financial Accounting II (3-0)3
Prerequisite: 60-709
Partnership accounting and accounting for installment and consignment sales. Accounting for nonprofit organizations, such as, governmental units, educational institutions, and hospitals.

60-711 Theory of Financial Reporting (3-0)3
Prerequisite: 60-612
Theory and rationale of corporate financial reporting with a study of the actual results found in current reporting practices of business firms. The strengths and weaknesses of financial reporting, current trends and future impact.

60-712 Controllership (3-0)3
Prerequisite: 60-612
Management control structure and processes are studied, generally by the case method. The controller's function is examined in terms of its functional responsibilities to other agencies both internal and external to the organization.

60-752 Accounting Information Systems (3-0)3
Prerequisite: 60-612
The design and development of computer-based information systems to insure that they are responsive to organizational needs.

64-600 Mathematics for Business Administration (3-0)3
Review of algebra. Elementary set theory and its applications. Mathematical functions. Matrix algebra and its applications. Exponential functions and logarithms. Limits, continuity and differentiations. Maximization of functions and its business applications. Antiderivatives and rules of integration. Applications of integral calculus. This is a remedial course and cannot be used as an elective.

64-601 Economics of the Firm (3-0)3
Prerequisite: 64-611
An analysis of how the market system operates. The examination of consumer behavior, production, and competition.

64-611 Quantitative Analysis (3-0)3
Prerequisite: 64-600 or equivalent
Introductory statistics and its role in business. Topics covered include variables and their distributions, sampling, theory, hypothesis testing, simple and multiple regression, correlation, and decision theory.

64-620 Public Finance and Monetary Policy (3-0)3
Prerequisite: 64-611
The role of government spending, taxation, and control of the money supply influencing the

performance of the national economy. Topics addressed include determination of aggregate income, fiscal policy, monetary policy, taxation, inflation, the foreign trade sector, and economic growth. The emphasis is on macroeconomic relationships and current policy issues.

66-602 Information Systems for Management **(3-0)3**
Use of computers to aid management decision-making in business. Concepts of computer hardware and software capabilities and limitations, systems analysis concepts.

66-603 Advanced Topics in Management Information Systems
Prerequisite: 66-602
Selected key topics in MIS such as software systems, on-line real-time systems, data telecommunications, data management and retrieval, data base management, distributed processing systems, project management, office automation, control and auditing, documentation standards, electronic funds transfer, legal aspects of data processing, and other topics.

66-622 Marketing **(3-0)3**
How marketing strategies and plans of a competitive enterprise are formulated, implemented, and adjusted over time. Behavioral and quantitative aspects are covered, as well as analysis of the environmental forces affecting marketing decisions.

66-629 Independent Study in Marketing **(3-0)3**
Prerequisite: 66-723

66-632 Business Financial Analysis **(3-0)3**
Prerequisite: 60-601
A study of financial principles and organization of business enterprise with emphasis on financial analysis, management of working capital, management of sources and cost of capital, and capital budgeting. Business cases, problems, readings, and reports.

66-651 Organizational Behavior **(3-0)3**
The relationship between the individual and the organization in terms of organization design, leadership, motivation, communications, group dynamics, conflict resolution, decision-making, interpersonal relations, change, and career development.

66-652 Human Resource Management **(3-0)3**
Prerequisite: 66-651
Recruitment, selection, training, human resource planning, compensation management, equal employment opportunity, performancce evaluation, management development, discipline, and employee health and safety. The role of the human resource executive in corporate management and strategic planning.

66-672 Operations Management **(3-0)3**
Prerequisite: 64-611
The techniques and models used in operations management. Topics include production design and process planning, layout of physical facilities, production standards and work methods, job evaluation, forecasting and scheduling, inventory systems, quality control, and the use of simulation in manufacturing operations.

66-673 Operations Research **(3-0)3**
Prerequisite: 64-611
Operations research techniques useful in business and management decision-making. Topics include classical optimization, linear programming, dynamic programming, queuing theory, Markov chains and simulation methods.

66-701 Starting New Ventures
The role of the entrepreneur in today's business world and indenifies the traits commonly associated with successful entrepreneurship. The processes of new venture selection and start-up are examined via the use of appropriate cases.

66-723 Marketing Analysis and Planning (3-0)3
Prerequisite: 66-622
Managerial decision-making aspects of marketing including design and use of models, marketing's organizational relationships, utilization of market research data, and performance evaluation and control through marketing audits.

66-724 Marketing Research (3-0)3
Prerequisite: 66-622
The formulation, execution, and interpretation of marketing research projects, within the broader context of a marketing intelligence system. Research design, data collection methods, and sampling theory.

66-725 Marketing Communications (3-0)3
Prerequisite: 66-622
The social economic role of promotion and the historical development of mass media and advertising. Advertising research, creation and production as a tool of marketing management.

66-726 Consumer Behavior (3-0)3
Prerequisite: 66-622
Application of theories and techniques from the behavioral sciences to the understanding of consumer problem identification and purchasing processes. Cases in the formulation of marketing strategies based upon appropriate behavioral models.

66-727 International Marketing (3-0)3
Prerequisite: 66-622
Cases in cultural dynamics, economics, political and legal restraints as they affect strategic planning for international business.

66-729 Independent Study in Marketing (3-0)3
Prerequisite: 66-723 and permission of instructor

66-731 Financial Management (3-0)3
Prerequisite: 66-632
The optimum management of funds in a business organization and the techniques of financial analysis. Topics include valuation of the firm, capital budgeting, cost of capital, decisions under uncertainty, management of working capital, and other related topics.

66-732 Financial Markets and Institutions (3-0)3
Prerequisite: 66-632
Analysis of the theory and practice of financial intermediation by institutions in the financial markets.

66-736 Portfolio and Security and Analysis (3-0)3
Prerequisite: 66-632
Development of investment theory as applicable to portfolio management and securities selection.

66-737 Seminar in Current Topics in Finance (3-0)3
Prerequisite: 66-632
Selected topics having current and future impact in the field of finance.

66-738 International Financial Management (3-0)3
Prerequisite: 66-632
The international dimension of the finance function of the firm. Financial constraints of the international environment and their effect on the standard concepts of financial management. The techniques of adapting risk analysis to the international situation. Study of international currency flows, monetary systems, forward cover and international banking policies.

66-739 Independent Study in Finance (3-0)3
Prerequisite: 66-732 and permission of instructor

66-752 Organization Design and Change **(3-0)3**
Prerequisite: 66-651
How general managers can create, rearrange and improve organization structures and sub-units. Identifies design and change methods for more efficiently controlling and directing behavior toward the achievement of corporate goals and strategies. This course integrates Organizational Behavior and Business Policy.

66-753 Compensation Management **(3-0)3**
Prerequisite: 66-651
Theories and practices in compensation management. Topics include equity, job analysis, job evaluation, legal issues, salary surveys, pay structure design, individual pay decisions, incentive plans, economic constraints and the role of unions.

66-754 Planning Management Careers **(3-0)3**
Prerequisite: 66-752 or permission of instructor
Two approaches to planning careers in management: 1) the assessment of personal growth and development through individual career stages and life cycles, 2) the analysis of managerial skill and task requirements created by different organizations at various stages of their own design and change.

66-759 Independent Study in Human Resource Management **(3-0)3**
Prerequisite: Permission of instructor

66-772 Operations Planning and Control **(3-0)3**
Prerequisite: 66-672
This course focuses upon the many complex decisions which an operations manager faces. Topics include the design of forecasting, production planning, inventory control, and quality control systems, and how each of these systems is integrated into the firm as a whole. Cases and readings will be used extensively.

66-773 Advanced Operations Research **(3-0)3**
Prerequisite: 66-673
Dynamic Programming, Integer Programming and Combinatorial models, Stochastic Programming models, Probabilistic Inventory models and Waiting Line models. The significance of the models, their potential problem-solving capabilities and limitations, including computational experience and applications.

66-774 Industrial Relations **(3-0)3**
A study of public policy toward labor-management relationships. Regulation by the National Labor Relations Board, collective bargaining, arbitration, civil rights, and the application of anti-trust law to unions.

66-779 Independent Study in Operations Management **(3-0)3**
Prerequisite: 66-772 and permission of instructor

66-781 Business Policy **(3-0)3**
This course is taken in the last semester of the program and emphasizes strategic long-range planning and organization to illustrate the interrelationship of the various functional areas of business.

66-783 International Business **(3-0)3**
Prerequisites: 66-622, 66-632, 66-651, 66 -672
Private versus government interests. The functional areas of international business operations, particularly marketing and finance.

66-789 Independent Study in General Management **(3-0)3**
Prerequisite: Permission of instructor

COLLEGE OF MUSIC

DEAN: GERALD LLOYD, *Professor;* B.M., M.M., College-Conservatory of Music, University of Cincinnati; Ph.D., Eastman School of Music, University of Rochester.

ASSISTANT DEAN: ERICH J. LEAR: B.M., M.A., D.M.A., University of Iowa.

GRADUATE COORDINATOR: WILLIS TRAPHAGAN, *Professor of Performance, Conducting;* B.M., Ithaca College; M.M., Boston University.

Faculty:

Dean Bouzianis, *Assistant Professor of Music Theory;* B.M., A.M., Boston University; M.M. National Conservatory of Greece.

Donald Bravo, *Professor, Music Education;* B.M., New England Conservatory; M.M., Boston Conservatory.

Jacqueline Charette, *Associate Professor of Music Theory and Chair, Academic Studies Department;* B.M., Rivier College; M.M., Ed. D., Boston University.

Alma O. Espinosa, *Associate Professor, Music History & Literature;* B.M., Eastman School of Music; M.M., Pius XII Institute; A.M., Ph.D. New York University.

Paul Gayzagian, *Professor of Music Education;* B.M., M.M., Ed.D., Boston University.

Antone Holevas, *Associate Professor, Music Theory;* B.M., Butler University; M.M., Boston University.

William Moylan, *Assistant Professor, Theory/Composition and Coordinator, Sound Recording Technology;* B.M., Peabody Conservatory, Johns Hopkins University; M.M., University of Toronto; D.A.; Ball State University.

Christopher McGahan, *Assistant Professor of Performance (Choral Ensembles);* B.A., University of Massachusetts-Amherst; M.M., University of Wisconsin-Madison; D.M.A., University of Illinois-Urbana.

Ingul Ivan Oak, *Associate Professor of Performance (Voice);* B.M., M.M., New England Conservatory.

John Ogasapian, *Professor, Music History and Literature;* B.M., M.A., Ph D., Boston University.

Natalo Paella, *Professor of Performance (Trumpet);* B.M., Louisiana State University; M.M. New England Conservatory.

Kay George Roberts, *Assistant Professor of Performance (Strings & Conducting);* B.A., Fisk University; M.M., M.M.A., Yale University.

Rawn W. Spearman, *Associate Professor, Academic Studies; Coordinator, Music Business;* B.S., Florida A.& M.,; M.A., Ed.D., Columbia University.

Anne Trenkamp, *Associate Professor, Music Theory;* B.A., Ph.D., Case-Western Reserve University; M.M., University of Michigan.

Robert White, *Assistant Professor, Music Education (Choral Ensembles and Consortium Artis Musicae);* B.M., New England Conservatory; A.M., Harvard University; Ph.D., Boston University.

General Admission Requirements

Applicants for admission to the Master of Music degree program must possess a bachelor's degree or its equivalent with a major in music. Those holding degrees in other disciplines will be expected to take prerequisite undergraduate courses for no graduate credit to bring their skills to a level commensurate with that attained by an undergraduate music major. Some prerequisites may be waived, at the discretion of the College, through

distinguished results on placement examinations and performance auditions.

All applicants are expected to present an undergraduate record of sufficient quality to assure a reasonable expectation of successful graduate achievement. Candidates for admission must submit the required Graduate School application forms and official transcripts of previous post-secondary education. (All transcripts must be mailed directly to the Graduate School from the institution at which such studies were undertaken).

The College of Music does not require the GRE Aptitude Tests for admission but uses the Miller Analogies for all programs, except Performance, instead of this test. Each department requires additional materials or examinations which must be completed or filed by the applicant. Please review the materials below for information on individual programs.

Additional Specific Program Requirements

1. Music Education: Miller Analogies Test scores; a teaching certificate or proof of teaching experience; three letters of recommendation as required by the Graduate School application from persons qualified to evaluate both musical and professional capabilities; and an essay of no more that ten (10) typewritten pages addressing the following points:

   a. Your purpose for pursuing graduate study in music education;
   b. Your present philosophy of education in general and music education in particular;
   c. An assessment of music education in your community;
   d. Your recommendations for improvement at all three levels: elementary, middle school and high school;
   e. Specific steps you would take, or are already taking to implement the improvements you recommend;
   f. A description of your concept of an "ideal" program of graduate study in music education, which would enable you to grow musically and academically, and which would contribute significantly to your effectiveness as a music educator.

2. Music Theory/Composition: The Miller Analogies Test scores; a portfolio of compositions equivalent to that required of undergraduate majors as specified in the College of Music undergraduate catalog; and at least one of the three required letters of recommendation from a professor in the candidate's previous institution who is in a position to assess the quality of previous work and potential for future development.

3. Music History: The Miller Analogies Test scores; a sample of expository writing showing research technique (e.g., a copy of an undergraduate thesis or term paper), and at least one of the three required letters of recommendation from a senior professor at the previous institution who is in a position to assess the quality of the scholarship and potential for significant scholarly contribution to music history by the applicant.

4. Performance: Performance applicants will be expected to demonstrate a high degree of achievement in their chosen performance medium

through the audition process. Auditions are held on specific published dates during each academic year, and applicants who meet the general admission criteria will be invited to attend the next scheduled audition following processing of the application materials. Applicants who live at too great a distance may submit a tape directly to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of their initial semester of matriculation. In addition, the three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skill and accomplishment of the applicant.

5. Performance/Conducting: Applicants for the Performance/Conducting program will be auditioned in both conducting and their major medium of performance. Those who live at too great a distance may submit video and audio tapes, respectively, to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of their initial semester of matriculation. Applicants must also present evidence of undergraduate studies in the following areas:

a. conducting
b. instrumentation and/or orchestration
c. studies in several areas of music performance representative of the families of musical instruments, i.e., strings, woodwinds, etc.

In addition, the three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skills and accomplishments of the applicant, as well as the applicant's potential as a conductor.

Placement Examinations and Advising

Successful candidates for admission will be assigned a faculty advisor and notified of registration dates and other pertinent information. Students should also be aware of the following requirements:

1. All entering graduate students are required to take PLACEMENT EXAMINATIONS in MUSIC THEORY and MUSIC HISTORY.

2. In addition, students admitted to the Music Education Program are required to take a PLACEMENT EXAMINATION in Music Education and to pass a PERFORMANCE AUDITION in their primary medium of performance.

Program Requirements

General Requirements: All Master of Music programs require at least 33 credits, including 74-596, Introduction to Graduate Study in Music; at least two semesters of Applied Music study in the major performance medium and at least two semesters of satisfactory ensemble participation. In addition, a thesis or recital(s) is/are required as follows:

1. Performance: Two public recitals and the submission of written program notes for each;

2. Performance/Conducting: A public performance as conductor and the submission of a related analytical document;

3. Music Education and Music History: A thesis on a topic approved by and under the supervision of appropriate departmental faculty;

4. Music Theory/Composition: Either a thesis or a composition, the nature of which shall be determined in consultation with the advisor and appropriate departmental faculty.

Distribution Requirements: While all programs offer flexibility of course selection in consulation with the student's advisor, some specific distribution is required by each program, in addition to the general requirements listed above.

1. Performance candidates must take 16 credits of specified applied music; 8 credits of major ensemble (where applicable); and 9 credits (3 courses, including 74-596) of music electives exclusive of ensembles.

2. Performance/Conducting candidates must take 12 credits of specified literature and techniques seminars; 6 credits of conducting practicum; and 9 credits (3 courses, including 74-596) of music electives exclusive of ensembles.

3. Music History candidates must take a minimum of 3 credits (one course) in music theory.

4. Music Theory/Composition candidates must take a minimum of 3 credits (one course) in music history, in addition to 74-596. Students must also elect a minimum of 15 credits (5 courses) in their specific area of concentration.

5. Music Education candidates must take 3 credits (one course) in music theory; 3 credits (one course) in music history in addition to 74-596; 3 credits (one course) in research in music education; a 3 credit education elective; and 12 credits (four courses) of music education electives, of which 3 credits (one course) may be a music education workshop.

Language Requirements: Music History candidates must demonstrate knowledge of German sufficient to read scholarly literature of their field in that language with adequate comprehension. Music Theory/Composition candidates must demonstrate a similar level of reading comprehension in either German or French. *Language requirements must be satisfied prior to taking the Comprehensive Examinations.*

Comprehensive Examinations: All degree candidates must pass a comprehensive examination in both music theory and music history, demonstrating their understanding of basis theoretical and historical concepts. These examinations are administered twice yearly on the first Thursday of each semester by the Department of Academic Studies.

In addition, Music Education candidates must pass a comprehensive examination in music education, and all candidates may expect to be examined in depth in their major area of concentration. Further information as to the nature and scope of the comprehensive examinations may be obtained from the advisor or the Department Chair.

Tramsfer Credits

From other institutions: Only matriculated students may transfer credit. To do so, students must file the appropriate Academic Petition, obtainable from the Graduate Office or the Coordinator. A matriculated student may transfer up to l0 credits earned with a B grade or better from another university toward a master's degree. The following regulations apply:

1. An official transcript and description of the course(s) must be submitted with the written petition.
2. The courses presented must be from an accredited institution authorized to grant graduate degrees.
3. The courses presented must not have been used in earning another degree.
4. The courses presented must be appropriate to the degree program for which the applicant is appying.
5. Transfer credit may not be granted for research seminars, clinical courses, practica, internships, or special projects.
6. Students wishing to transfer credit must file, *within the first semester of matriculation*, the appropriate Academic Petition.

From the University of Lowell: A student who has taken courses at the University of Lowell on a non-degree basis and wishes to transfer these credits to a degree program may do so only with the approval of the department in which the student is matriculated. No more than l2 total credits earned as a non-degree student, or in combination with credits earned at another institution, may be transferred to a degree program.

MUSIC EDUCATION

The Music Education curriculum is based on the assumption that music educators should have a comprehensive knowledge of the subject matter of music, an awareness of current theory and practice in music education and a familiarity with recent developements in general education; particularly in administration, supervision, curriculum and research.

Course Offerings

73-551 Research in Music Education **(3-0)3**
Methods of scientific inquiry in music education. The gathering, correlating, evaluation and reporting of quantitative and qualitative data. Experimental designs in music education. Preparation of thesis prospectus.

73-564 Affective Learning through Music **(3-0)3**
The integration of the affective domain into the music education curriculum.

73-566 Current Issues in Music Education **(3-0)3**
Examination and evaluation of current trends in music education and general education.

73-570 Administration and Supervision in Music Education **(3-0)3**
Contemporary concepts of supervision and administration, including philosophy, techniques, curriculum, budget, community and personal relationships, and staff evaluation.

73-580/589 Workshops in Music Education **(3-0)3**
Specific concentrated experiences in various facets of music education skills, including Orff-Kodaly (580, 58l), beginning and advanced; Springs (582); Brass (583); Woodwinds (584); Marching Bands (585); Bands (596); Orchestra (587); Choral (588); Music Theater; Computer Applications (589). Workshops are generally conducted during the summer in two-week, all day sessions.

73-590/599 Workshops: Special Areas **(3-0)3**
Specific concentrated experiences in specialized facets of music education conducted by visiting or resident experts in the area. Areas are of an exceptional nature; e.g., Dalcroze Eurhythmics, Learning Disabled Child and Music, are offered as announced.

73-601 Seminar in Music Education **(3-0)3**

73-796 Directed Study (Thesis) in Music Education **(3-0)3**

MUSIC THEORY AND HISTORY

Course Offerings in Music Theory

71-500 Theory Review **(3-0)3**
A review of common-practice part writing and analysis. Credit cannot be applied toward the Master of Music degree requirements.

71-501 Analytical Techniques **(3-0)3**
Formal, contrapuntal and harmonic analysis of common practice repertoire.

71-503 Theoretical Concepts **(3-0)3**
A study of major concepts in music theory from Rameau to the present.

71-512 Studies in the Perceptual Analysis of Music **(3-0)3**
An examination of current ideas pertaining to the interrelationship between human perceptual mechanisms and musical patterning.

71-526 Analysis of Contemporary Music **(3-0)3**
Formal, contrapuntal and harmonic analysis of twentieth century repertoire, both serial and non-serial.

71-601 Topics in Common Practice Analysis **(3-0)3**

71-626 Topics in Contemporary Musical Analysis **(3-0)3**

71-795 Directed Study in Composition (Thesis) **(3-0)3**

74-539 Eighteenth and Nineteenth Century American Music **(3-0)3**
Examination of various aspects of American art music during its formative decades.

74-548 J.S. Bach **(3-0)3**
Representative music of the composer. Emphasis on the stylistic traits and latest research reordering the chronology of Bach's work.

74-549 Mozart (3-0)3
An in-depth study of the development of Mozart's compositional style through an examination of representative works.

74-564 History of Music Theory (3-0)3
A survey of the main currents of musical notation, theory and philosophy from the classical and patristic philosophers to the present.

74-567 Musicology and Research I (3-0)3

74-568 Musicology and Research II (3-0)3

74-596 Introduction to Graduate Study in Music (3-0)3
Research techniques, bibliography, form and style in the preparation of formal scholarly papers in music.

74-597 Topics in Musicology I (3-0)3

74-598 Topics in Musicology II (3-0)3

74-661 Seminar in Medieval Music (3-0)3

74-662 Seminar in Renaissance Music (3-0)3

74-663 Seminar in Baroque Music (3-0)3

74-664 Seminar in Music of the Classic Period (3-0)3

74-665 Seminar in Romantic Music (3-0)3

74-666 Seminar in Twentieth Century Music (3-0)3

74-667 Seminar in Musicology (3-0)3

74-668 Seminar in Musicology (3-0)3

74-796 Directed Study (Thesis) in Musicology (3-0)3

PERFORMANCE

Course Offerings

72-501/502 Applied Keyboard IX, X (1/2-10)2
72-511/512 Applied Voice IX, X (1/2-10)2
72-521/522 Applied Woodwinds IX, X (l/2-10)2
72-531/532 Applied Brass & Percussion (1/2-10)2
72-541/542 Applied Strings Ix, X (l/2-10)2
72-551/552 Performance Keyboard VII, VIII (1-20)4
72-561/562 Performance Voice VII, VIII (1-20)4
72-571/572 Performance Woodwinds VII, VIII (1-20)4
72-581/582 Performance Brass & Percussion VII, VIII (1-20)4
72-591/592 Performance Strings VII, VIII (1-20)4
72-593/594 Applied Music (1/2-10)2
72-651/652 Performance Keyboard IX, X (1-20)4
72-661/662 Performance Voice IX, X (1-20)4

72-671/672 Performance Woodwinds IX, X **(1-20)4**
72-681/682 Performance Brass & Percussion IX, X **(1-20)4**
72-691/692 Performance Strings IX, X **(1-20)4**
72-693/694 Performance Applied Music **(1-20)4**

75-550 Seminar in Instrumental Conducting Techniques **(3-0)3**
A study of analytical, rehearsal and baton technique in reference to the instrumental conductor. Program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75-552 Seminar in Choral Conducting Techniques **(3-0)3**
A study of analytical, rehearsal and baton technique in reference to the choral conductor. Vocal techniques, program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75-595 Directed Study and Research in Performance **(3-0)3**

75-650 Conducting Practicum and Seminar I **(3-0)3**
An extension of the materials and skills developed in Literature and Techniques Seminars, through practical application, under faculty direction, in conjunction with one or more performing ensembles.

75-652 Conducting Practicum and Seminar II **(3-0)3**
A continuation of 75.650 to a more advanced level, culminating in the presentation of a public conducting performance and a related analytical document.

75-654 Seminar in Instrumental Literature **(3-0)3**
A study of stylistic elements, orchestration, formal structure, problem analysis and historical perspective in a selection of standard works from the orchestral and band repertoire. Independent research is primary element of this course.

75-656 Seminar in Choral Literature **(3-0)3**
A study of style, structure, text and historical perspective in relation to the main body of literature for chorus and orchestra. Independent research is primary element of this course.

75-695 Directed Study and Research in Performance **(3-0)3**

75-696 Directed Study and Research in Performance **(3-0)3**

75-796 Directed Study and Research in Performance **(3-0)3**

76-501 Graduate Vocal Ensemble **(0-2)1**

76-502 Graduate Instrumental Ensemble **(0-2)1**

76-601 Graduate Vocal Ensemble **(0-4)2**

76-602 Graduate Instrumental Ensemble **(0-4)2**
(Graduate students may fulfill ensemble participation requirements through membership in such performing organizations as Orchestra, Wind Orchestra, Wind Sinfonia, Chamber Singers, etc., or with permission through participation in combinations of smaller, more specialized ensembles.)

COLLEGE OF PURE AND APPLIED SCIENCE

ACTING DEAN: NICHOLAS J. RENCRICCA, *Professor;* B.S., St. Francis College; M.S., St. John's University; Ph.D., Boston College.

ASSISTANT DEAN: RAYMOND F. HARDY; B.S., M.S., Lowell Technological Institute

DEPARTMENT OF BIOLOGICAL SCIENCES

DEPARTMENT CHAIRPERSON: THADDEUS V. OSMOLSKI, *Associate Professor;* B.S., University of Rhode Island; Ph.D., Brown University.

GRADUATE COORDINATOR: ILZE B. SKARE, *Associate Professor;* B.A., University of Connecticut; Ph.D., Duke University.

Faculty

John I. Bruce, *Professor;* B.S., Morgan State College; M.S., Ph.D., Howard University
Robert M. Coleman, *Professor;* B.S., Bates College; M.S., University of New Hampshire; Ph.D., University of Notre Dame.
David T. Eberiel, *Associate Professor;* B.S., Bethany College; M.S., Tufts University; Ph.D., Boston College.
Jerome L. Hojnacki, *Professor;* B.S., Southern Connecticut State College; M.S., University of Bridgeport; Ph.D., University of New Hampshire; M.H.A., Clark University.
Ethel N. Kamien, *Professor and Associate Chairperson of Department;* B.A., Brooklyn College; M.S., Ph.D., University of Wisconsin.
Robert D. Lynch, *Associate Professor;* A.B., Northeastern University; M.S., D.Sc., Harvard School of Public Health.
John C. Mallett, *Associate Professor;* B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.
Ezequiel R. Rivera, *Professor;* B.A., Sul Ross State College; M.S., Purdue University; Ph.D., University of Texas (Austin).
Lee-Jun C. Wong, *Associate Professor;* B.S., National Taiwan University; Ph.D., The Ohio State University.

Master of Science Degree Program

The Master of Science in Biological Sciences and the Master of Science in Biological Sciences-Biotechnology Option are designed to afford the student an opportunity for advanced study and training necessary to conduct independent research at a professional level and to be successful in today's competitive academic and research market. Students in the program will be encouraged to explore quantitative approaches to the solution of problems in the basic and applied biological sciences. Depending on their career goals, students may choose research or coursework options within the Department, or the interdisciplinary Biotechnology option. All Candidates for the M.S. degree will be expected to demonstrate that they have mastered sufficient knowledge and skills to pursue independent and creative research activities.

Faculty Research Interests
Each member of the graduate faculty in the Department of Biological Sciences has an active research career as evidenced by numerous publications, attendance and participation in conferences and acquisition of grants and contracts. Many have served as fellows in postdoctoral research programs.

Faculty have affiliation and research collaboration with Harvard Medical School, Harvard School of Public Health, Boston University, Dana Farber Cancer Institute, Brigham Young University, University of Texas, Mahidol University (Thailand), Academy of Medical Sciences (U.S.S.R.), Ain Shams University (Cairo, Egypt), The University of Jordan (Amman, Jordan), and the National Oceanographic and Atmospheric Administration, National Fisheries Lab.

The following is a list of current faculty research interests in which opportunities for student thesis or project research exist:

Lipid biochemistry and cardiovascular disease
Metabolic regulation, nutritional biochemistry, and cell biology
Structure-function relationship of eukaryotic chromatin
Immunobiology of host-parasite relationships
Hybridoma and monoclonal antibodies
Genetic mapping, DNA sequence analysis, and molecular cloning of viral DNAs
Biological ultrastructure, cytology, plant anatomy and physiology, biomembranes
Ecology, aquatic biology, and ecological physiology
Developmental and chemical control of aging and senescence in plants
Erythropoietic regulation; kinetics of stem cell proliferation and differentiation; malariology; hyperbaric oxygen-induced toxicity; *in vivo* and *in vitro* assessment of drug toxicity
Waste biomass conversion to fuel alcohol
Microbial competition; effects of microorganisms on biopolymers
Effects of environmental agents on rodent karyotypes

Research and Teaching Facilities
The department is housed in modern teaching and research facilities which include service areas such as animal quarters, greenhouse, X-ray facilities, temperature-controlled animal and plant cell culture incubation equipment and dark rooms. The department also maintains a primate research center. Research instrumentation includes transmission electron microscopes, ultracentrifuges, UV-visible spectrophotometer, gas chromatographs, fluorometer, atomic absorption spectrophotometer, liquid and deep-well crystal scintillation spectrometers, Coulter counter, electrophoresis equipment (PAGE, isoelectric focusing, and sequencing). HPLC and other chromatography equipment, fermenters, microcomputers, and a marine aquarium. The department also houses computer terminals that tie into the University Cyber 170 main frame computer.

Entrance Requirements and Procedures
Entering graduate students are expected to have a sound preparation not only in the biological sciences, but also in chemistry, physics, calculus, and statistics. A student found deficient in any of these areas may be required, during the first year of residence, to take appropriate courses to eliminate the deficiencies. Entering students are assigned a departmental adviser who helps plan the first semester's program of study, acquaints them with research opportunities in the department, and assists in selecting a research supervisor.

Degree Requirements
A minimum of 30 semester hours of graduate level work is required for the Master of Science degree in Biological Sciences. The student has a choice of three options: thesis, project, or non-thesis. Core requirements for all options include 2 semesters (4 credits) of Graduate Seminar (81-601, 602) and 12 credits of formal course work selected from departmental electives (exclusive of thesis, project, problems, or other directed studies). The remaining 14 credits may be satisfied by additional electives within the department (thesis, project, problems or more course work), by transfer credit for approved graduate level biological sciences courses taken at other accredited institutions (10 or maximum), or by graduate courses taken in related disciplines within the University (e.g. chemistry, environmental science, radiological sciences; 8 or maximum). There is no formal language requirement.

Thesis Option
In choosing this option, the student concentrates on an in-depth independent scholarly investigation of a contemporary biological problem. Credit is allowed for 6-12 semester hours of Graduate Research in Biology (81-701). The student chooses a Graduate Committee, which generally consists of the thesis advisor and at least two additional members, one of whom must be from within the Department. The student must orally present to the Committee a proposal of intended research and obtain the Committee's approval of the research topic. After completing the Master's thesis, the student must present a defense of his/her work in an open seminar.

Project Option
The project option is designed for independent laboratory investigations of a more limited nature than the thesis option. Generally, a project is completed in one semester and credit is given for 1-3 semester hours of Graduate Project in Biology (81-702). Occasionally, a project may be extended to a maximum of 6 semester hours. A student who registers for more than 3 credits of project is required to present the results of his investigations in an open seminar.

Non-Thesis Option
This option offers course work in breadth and depth, and may be of special interest to secondary school science teachers, individuals already employed in academic, hospital, or industrial laboratories, or others who may not be

able to participate in the thesis or project options because of scheduling conflicts. The non-thesis option may be completed during the day on a full-time basis or in the evenings on a part-time basis by enrolling in evening courses offered through the Division of Continuing Education.

Professional Internship credit (81-500; 3 cr.) may be requested by individuals who present satisifactory evidence (in the form of a written statement from their supervisor) of having at least one year of experience in secondary school science teaching, or in a hospital, academic, or industrial laboratory setting.

STUDENTS WHOSE PROFESSIONAL GOALS ARE TO CONTINUE ON FOR THE PH.D. DEGREE, OR WHO PLAN TO SEEK EMPLOYMENT IN ACADEMIC OR INDUSTRIAL RESEARCH LABORATORIES AS TECHNICIANS OR JUNIOR SCIENTISTS ARE STRONGLY URGED TO CHOOSE THE THESIS OR PROJECT OPTION IN ORDER TO SUCCESSFULLY COMPETE FOR SUCH POSITIONS. STUDENTS IN THE NON-THESIS OPTION SHOULD ENDEAVOR TO SELECT COURSES WITH ACCOMPANYING LABORATORIES WHENEVER POSSIBLE SO THAT FACULTY MAY PREPARE MEANINGFUL LETTERS OF RECOMMENDATION TO POTENTIAL EMPLOYERS.

Evening Courses (Continuing Education)

Biological Sciences electives offered through the Division of Continuing Education are interchangeable with the corresponding day school courses, and admission requirements and degree completion requirements for both the full-time day program and the part-time evening program are identical.

However, not all day courses are regularly available in the evening program, so a part-time student's progress toward the M.S. degree will depend not only on his/her available time and abilities, but also on the scheduling of electives. In some instances, with the consent of a faculty member, an evening program student may elect the thesis or project option. An evening program Graduate Coordinator is available to advise Continuing Education students on how to best plan their course of study.

M.S. in Biological Sciences - Biotechnology Option

The Biotechnology Option offers an interdisciplinary program of advanced study and research training in the increasingly expanding field of biotechnology. Provisions are made to address the varied interests of students and to permit optimal latitude for either research-oriented or production-oriented training.

A candidate who selects the Biotechnology Option for the Master of Science in Biological Sciences must complete original research in one of the recognized areas of biotechnology or present an innovative application of technology or engineering principles to a biological problem of economic interest. The nature and extent of the investigation will determine its degree credit value. Candidates must also complete two semesters of Graduate Seminar and take a minimum of 15 credit hours of course work selected from an approved list of courses offered by the departments of Biological

Sciences, Chemical Engineering, Chemistry, and Clinical Laboratory Science. The design of the academic program is the responsibility of the students and their advisory committees.

Five-Year B.S./M.S. Program

In recognition of the need for advanced training beyond the Bachelor of Science level in biological sciences, the following represents a program by which outstanding undergraduates can pursue an accelerated five-year course of study leading to the B.S. and M.S. degrees in Biological Sciences.

The first two years of undergraduate study will be identical to that which is specified for students enrolled in the current four-year B.S. program.

Sophomores who express an interest in this program will be evaluated by the Department Graduate Selection Committee. Those students deemed commendable by the Committee will be advised as to the correct procedure for successful completion of their B.S. degree, as well as a course of study toward the M.S. degree.

In the junior year, the student will be expected to take one additional undergraduate elective course each semester. During the second semester of the junior year and upon approval and recommendation by the Department Graduate Selection Committee, the student will file formal application for admission to the Graduate School. This does not require the student to have taken the GRE examination. The Committee decision will be based on: (a) overall grade point average, (b) grade point average in selected subjects, (c) recommendations by Department faculty, and (d) a one-year minimum residency requirement at the University of Lowell. Upon approval and recommendation by the Dean of the Graduate School, the student may be allowed to pursue graduate studies during the senior year and officially becomes a provisional graduate student in the second semester of the senior year.

During the senior year, the student will be permitted to take up to two graduate-level courses each semester, which will be applied towards the M.S. degree. Although advanced undergraduate (i.e. 400 level) courses are acceptable, no more than two such courses will be allowed towards the M.S. degree. It should be emphasized that the total number of credits for the combined degrees must be greater than the minimum number of credits required for both the undergraduate and graduate degrees. For example, if the University B.S. requirement is 120 credits, the student may, with approval, transfer any additional graduate-level credits toward the M.S. degree, excluding those used for the B.S. degree.

Upon successful completion of the fourth year of study, the student will be awarded the B.S. degree and then be recommended for full matriculation status by the Department Graduate Selection Committee and the Dean of the Graduate School, prior to the fifth year of study. If the student chooses not to continue toward the M.S. degree (or fails in the fifth year), this does not alter receipt of the B.S. degree.

Although the options exist for taking an overload in any semester and/or registering for one or more summer sessions, they are not a requirement of this program. However, students wishing to gain a full research

experience will be encouraged to initiate their research as early as possible (i.e. during the junior to senior year summer session).

During the fifth year, the student will complete the M.S. degree by taking two 2-credit Graduate Seminar courses and the remaining thesis, project or formal course work credits necessary to fulfill the 30 credit requirement.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM (Biochemistry Option)

The Department of Biological Sciences and the Department of Chemistry have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. This program draws upon the special and diverse talents of both faculties, and provides students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Admission Requirements and Removal of Undergraduate Deficiencies

Admission to the program requires demonstration of an acceptable B.S., B.A., or M.S. degree in chemistry, biology, biochemistry or other related science. Students will be expected to have completed two semesters each of General, Organic and Physical Chemistry as well as Introductory Biology. Deficiencies in any of these areas must be removed by enrolling in the corresponding undergraduate course during the first year in the program.

Academic Standards for Retention in the Biochemistry Program

The graduate student is expected to maintain an average of B or better in all his/her graduate-level courses. If at any time a student earns two C's or BC's, or any grade lower than C, actions such as warning, probation, loss of degree candidacy, etc. will be taken by the Biochemistry Program Committee.

Language Requirements

A dictionary reading knowledge of one of the three languages, German, Russian or French, is required. However, this must not be the student's native tongue. The language requirement may be satisfied by any one or combination of the three options:

a. By passing an examination given by the Graduate Committee of the Chemistry Department.

b. By transferring from another institution a year course with B or better grade beyond the first year.

c. By passing with a grade of B or better the language courses: French 50-103, 50-104; German 51-113, 51-114; Russian 53-113, 53-114.

In addition, the student must acquire facility in one additional tool. This may be a second language, computer programming, statistics, advanced mathematics or other skills appropriate to the student's area of research.

Degree Requirements
A minimum of 45 credits beyond the bachelor degree level are required in coursework exclusive of thesis and seminar. Eighteen of these credits are in Chemistry/Biochemistry core courses (lists A and B). The remaining nine may be selected from any Chemistry Department graduate courses, or approved biochemistry electives offered by the Department of Biological Sciences (lists C and D).

A. **Required Courses** *(12 credits):*

			Credits
81-550	(84-550)	Biochemistry I	3
81-551	(84-551)	Biochemsitry II	3
81-554	(84-554)	Techniques in Biochemistry	2
81-555	(84-555)	Special Techniques in Biochemistry	1
	84-538	Biochemical Mechanisms	3

B. **Prescribed Electives:** A minimum of six credits must be selected from the following list:

84-523	Organic Reaction Mechanisms and Structure	3
84-527	Stereochemistry	3
84-532	Advanced Physical Chemistry	
84-568	**Structural Analysis**	**3**

C. **Electives:** A minimum of six credits may be selected from any Chemistry Department graduate courses and/or the following approved biochemistry courses offered by the Department of Biological Sciences:

81-503	Biochemistry of Metabolic Disorders	3
81-529	Biochemical Aspects of Heart Disease	3
81-565	Biochemistry of Micronutrients	3
81-567	Recombinant DNA Techniques	3
81-569	Recombinant DNA Laboratory	1
81-576	Cell Culture and Hybridoma	2
81-578	Cell Culture and Hybridoma Laboratory	1
81-585	Eukaryotic Gene Expression	3

D. **Additional Electives:** A minimum of three credits must be selected from any of the graduate courses offered by the Department of Chemistry or the Department of Biological Sciences.

Seminars
During each semester in residence all full-time students must register for a one-credit seminar course. The student is expected to prepare two one-hour presentations during his/her residence, and to attend one seminar each week, as required by the Chemistry Department.

Journal Club
Once admitted to candidacy for the Ph.D. (generally at the end of the second year) each student will participate in a journal club to discuss recent articles from assigned journals.

Research

A. Initiation of Research - Preceptor Selection Procedure

The dissertation research of each graduate student may be initiated at any time but not later than the end of the second semester in the program. The student is advised to make serious efforts, prior to the summer following his/her first entrance to the program, to initiate faculty research interviews and attempt to identify the area of his/her research interest and particular research group which may be suitable for pursuing his/her research goals.

B. Advisory Committee

After the student has chosen his/her research preceptor, an Advisory Committee will be appointed to monitor the progress of the student's research at least twice a year. It is the student's responsibility to submit a typewritten semi-annual progress report to the Advisory Committee with a copy forwarded to the Biochemistry Program Committee. The due dates of such reports are January 1 and July 1 of each year. The advisory committee will be a permanent part of the student's examination committees.

Examinations

A. Qualifying Examination

If the average letter grade for Biochemistry I and II is less than B, the student is required to pass an oral examination in biochemistry administered by the Biochemistry Program Committee. Incoming students wishing to receive credit for an undergraduate biochemistry course may also be requested to pass this examination. Petition to take the examination may be made to the Biochemistry Program Curriculum Committee. Failure to achieve either the necessary letter grade average in Biochemistry I and II or a passing grade on the Qualifying Examination will be reason for review of the candidate's status in the program. The student will be advised either to withdraw from the program or to take the examination again.

B. Comprehensive Examination

Part 1. *The cumulative examination*

Ten cumulative examinations will be offered during the academic year, each worth 10 points. The subject material for these exams will be announced at least 2 weeks in advance of the exam date. To satisfy the requirements, each student must score a total of 50 points by the end of their second year in residence. Any student failing to do so may petition to the Program Committee for an extension which will consist of the next 10 consecutive exams. Denial of this petition of failure by the student to acquire 50 points in the next 10 consecutive exams will mean termination from the program with the award of an M.S. degree (assuming that all requirements for that degree have been completed). The student may apply for re-entry into the Ph.D. program after successful completion of the M.S. program.

Part 2. *Non-thesis research proposal*
Within six months of satisfying the cumulative exam requirement, the student will be required to present and defend, orally, a research proposal in an area of biochemistry other than that of his/her thesis. An outline of the proposed research will be distributed to the Examination Committee at least one week prior to the examination.

The examining committee will be composed of the student's Advisory Committee and three additional faculty members chosen after consultation of the student with his/her preceptor. The student should consult his/her preceptor in establishing this committee. All members of the University Community are welcome to attend these examinations.

Admission to Candidacy for the Doctorate
To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average.
2. Pass the General Examination and, if necessary, the qualifying examination.
3. Fulfill the language requirement (as outlined by the Chemistry Department).
4. Secure approval of his/her research preceptor and the biochemistry committee.

When these requirements have been fulfilled, the Biochemistry Program Curriculum Committee will recommend that the graduate coordinator of the Department of Chemistry notify the Dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

81-500 Professional Internship **(3-0)3**
Credits will be given to qualified individuals who have at least one year experience in secondary school science teaching, or in a hospital, academic or industrial laboratory setting.

81-501, 502 Selected Topics in Biology **(3-0)(3-0)6**
Current topics in various fields of biology presented in lecture, seminar or discussion groups. Subject matter varies depending on interests of instructors and needs of students. May be repeated for credit when course content differs.

81-503 Biochemistry of Metabolic Disorders **(3-0)3**
Prerequisites: Physiology and Biochemistry
This course deals with the biochemistry, pathophysiology, detection and treatment of a number of disturbances in lipid and carbohydrate metabolism including: diabetes, obesity, alcoholism, heart disease and glycogen storage diseases.

81-506 Physiological Ecology **(3-0)3**
Prerequisites: Quantitative Ecology or equivalent
A consideration of physiological evolutionary and environmental aspects of interactions between organism and environment with special emphasis on homeostatic adaptations to biotic and abiotic environmental fluctuations. Concurrent registration in 81-508 is required for Biology majors.

81-508 Physiological Ecology Laboratory **(0-3)1**
A series of laboratory investigations designed to illustrate basic homeostatic adaptations enabling organisms to maintain internal constancy in a variable environment.

81-510 Limnology **(3-0)3**
Prerequisites: Principles of Biology and Ecology
Introduction to freshwater environment, considering geology, chemistry and physics of waters as they affect flora and fauna in standing and flowing water. Attention is addressed to basin and channel morphometry, thermal, photic, hydrologic and solvent properties of the medium.

81-512 Limnology Laboratory **(0-3)1**
A series of laboratory exercises designed to emphasize the material covered in 81-510.

81-518 Experimental Hematology **(3-0)3**
Prerequisite: Mammalian Physiology or equivalent
Physiology of the erythropoietic system, with emphasis on the proliferation and differentiation of hemopoietic stem cells. Abnormalities and perturbations resulting in hematologic diseases will be included for discussion.

81-520 Experimental Hematology Laboratory **(0-6)2**
A series of laboratory exercises and projects designed to employ basic and advanced techniques in hematology and which emphasize the material covered in 81-518.

81-522 Plant Physiology **(3-0)3**
Prerequisite: Organic Chemistry or equivalent
Co-requisite: 81-524
A critical study of the physiological processes which occur in living plants, with emphasis on the angiosperms. Topics treated are growth and development, water relations, mineral nutrition, respiration, photosynthesis, and nitrogen metabolism. A term paper is required.

81-524 Plant Physiology Laboratory
A series of laboratory experiments and analyses designed to illustrate the material covered in 81-522.

81-529 Biochemical Aspects of Heart Disease **(3-0)3**
Prerequisites: Physiology and Biochemistry
Abnormalities in carbohydrate, lipid and protein metabolism which occur in the heart, blood and arteries during the development of atherosclerosis. Current biochemical methods employed in cardiovascular research.

81-541 Advanced Topics in Cell Biology and Physiology **(3-0)3**
Prerequisite: Biochemistry
Structure and function of the cell will be discussed in detail: (a) the anatomy and biochemistry of cellular membranes, (b) transport mechanisms,
(c) systems for motility, (d) properties of excitable cells, (e) energy transduction mechanisms. May be repeated for credit when content varies.

81-542 Cell Biology **(3-0)3**
Prerequisite: Biochemistry
Co-requisite: 81-544

Ultrastructure and biochemistry of eukaryotic cells: cell membranes and organelles; energy capture and transduction; histochemical and biochemical studies of organelles at the optical and electron microscopic level; cytogenetics; brief discussion of prokaryotic cells. A substantial library investigation is required.

81-544 Cytology Laboratory **(0-3)1**
Co-requisite: 81-542
Introduction to the optical microscope as an analytical tool. Analysis of biological ultrastructure at the optical and electronmicroscopic level. Cell fractionation. Chromosome preparations. One substantial ultrastructural analysis required.

81-548 Principles of Biochemistry I **(3-0)3**
Prerequisites: Organic chemistry (Physical Chemistry is recommended)
Primarily for M.S. students in Biological Sciences. Lectures and text assignments on the subjects of protein, carbohydrates, lipid, enzyme and membrane biochemistry will be supplemented with research journal readings.

81-549 Principles of Biochemistry II **(3-0)3**
Prerequisite: 81-548 or equivalent
This course is a continuation of 81-548 and will include discussions on all aspects of amino acid and nucleic acid metabolism and protein biosynthesis.

81-550 (84-550) Biochemistry I **(3-0)3**
Prerequisites: A course in Physical Chemistry or permission of instructor. Required of all Ph.D. students in the Biochemistry Option
Course content and requirements are similar to those in 81-548 except that a term paper or seminar presentation based on current published research will be assigned.

81-551 (84-551) Biochemistry II **(3-0)3**
This course is a continuation of 81-550 and will include topics similar to 81-549.

81-554 (84.554) Techniques in Biochemistry **(1-5)2**
Prerequisite/co-requisite: Biochemistry. Required of all Ph.D. students in the Biochemistry Option
Emphasis on common techniques and instrumentation employed in modern research laboratories. An independent laboratory project will be required.

81-555 (84-555) Special Techniques in Biochemistry **(1-2)1**
Prerequisite: 81-554/84-554 or equivalent. Required of all Ph.D. students in the Biochemistry Ph.D. Option.
A course designed to familiarize the student with selected techniques not covered in 81-554.

81-561 Electron Microscopy - Theory **(3-0)3**
Prerequisites: Biochemistry and permission of instructor
An introduction to the theory of electron microscopes and electron optics. Preparation of biological specimens for electron microscopic viewing and photography. Analysis of data obtained with electron microscopic techniques. Applications in biology will be discussed.

81-562 Electron Microscopy - Laboratory **(0-9)3**
Prerequisite: 81-561, Permission of Instructor
Operation of Scanning and Transmission Electron Microscopes. Project required of all students. Use of ancillary optical equipment.

81-564 Experimental Hematology: A Study of Current Literature (3-0)3
Prerequisite: 81-518 or equivalent
Group discussions of contemporary literature in experimental hematology. Mediators of blood cell production will be assessed relative to hemopoietic stem cells proliferation and differentiation. Included are papers dealing with hematologic diseased states.

81-565 Biochemistry of Micronutrients in Mammals **(3-0)3**

Prerequisites: Animal Physiology, Biochemistry

Lectures and journal readings will be presented on the biochemistry of selected vitamins, minerals and other nutrients required in small amounts by mammals.

81-567 Recombinant DNA **(2-0)2**

Prerequisites: Genetics, Biochemistry or equivalent

A study of the principles and specialized techniques of cloning, purifying, and manipulating recombinant DNA molecules. Independent literature review or research proposal required. Concurrent registration in 81-569 required for Biological Sciences majors.

81-569 Recombinant DNA Laboratory **(0-3)3**

A series of laboratory experiments and independent projects designed to illlustrate current recombinant DNA techniques.

81-572 Virology **(3-0)3**

Prerequisites: Genetics and Biochemistry

A study of bacterial and animal viruses including viral structure, modes of replication, biochemistry of the infected cell, genetic properties, and viral oncogenesis. Emphasis is on virus-cell interactions at the molecular level. A term paper is required.

81-574 Virology Laboratory **(0-3)1**

Laboratory experiments cover current techniques in bacterial and animal virology. Included are virus propagation and titration, biochemical, biophysical, and genetic analysis of viral nucleic acids and proteins, and cell structure techniques. Some independent laboratory work required.

81-576 Cell Culture and Hybridoma **(0-3)3**

Prerequisites: Genetics, Biochemistry (Immunology recommended)

Co-requisite: Cell Culture and Hybridoma Lab

Lectures and readings on the biology and culture of cells *in vitro* as well as the specialized methodologies necessary for hybridoma technology. Term paper or seminar is required.

81-578 Cell Culture and Hybridoma Laboratory **(0-3)1**

Prerequisite or Co-requisite: Cell Culture and Hybridoma

A series of exercises demonstrating the principles presented in 81-576. Techniques will include: medium preparation, standard culture procedures and hybridoma methodology. Independent project required.

81-585 Eukaryotic Gene Expression **(3-0)3**

Prerequisites: Genetics and Biochemistry

A study of the regulation of gene expression in eukaryotic cells. Emphasis will be given to the structure and function of DNA and chromatin, and transcriptional and post-transcriptional control of gene expression. A term paper on current research topics is required.

81-593 Immunobiology **(3-0)3**

Prerequisites: Microbiology and Biochemistry

A study dealing with the biology of the immune response with sections on antibody production, reaction with antigen, suppression, tolerance, protection and injury. Concurrent registration in 81-595 is required for biology majors. Original research proposal required.

81-595 Immunobiology Laboratory **(0-3)1**

A series of basic laboratory exercises dealing with the preparation, isolation and characterization of antigens, antibodies and effector cells. Semester project required.

81-601, 602 Graduate Seminar in Biology **(2-0)(2-0)4**

Required of all M.S. students

Presentation of individual reports by students on advanced topics, original research, or journal articles.

81-651, 652 Selected Topics in Biology (3-0)3-0)6

Prerequisite: Graduate students only, Permission of Instructor

Selected topics and recent advances not covered in regular courses. Content varies from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary biology.

81-701 Graduate Research in Biology (0-9)3 to (0-18)6

An independent investigation of a problem which has been approved as a suitable subject for a Master's Thesis.

81-702 Graduate Project in Biology (0-3)1 to (0-9)3

An independent study or laboratory project which has been approved as a suitable subject for a Master's Project.

81-751, 752 Problems in Biology (0-3)1 to (0-9)3

Prerequisite: Permission of instructor

Special research or laboratory projects, or extensive literature surveys, undertaken by the student to expand his/her knowledge in specific fields not necessarily related to his/her thesis.

82-551 Human Sexuality: Current Perspectives (3-0)3

(This course does not count towards the M.S. degree in Biological Sciences). The biological, psychological, and sociological parameters of human sexual expression are examined. An extensive project showing evidence of in-depth academic investigation will be required.

DEPARTMENT OF CHEMISTRY

DEPARTMENT CHAIRPERSON: ARTHUR C. WATTERSON, *Professor;* B.S., Geneva College; Ph.D. Brown University.

DEPARTMENT COORDINATOR: EUGENE F. BARRY, *Professor;* B.S., Villanova University; Ph.D., University of Rhode Island.

Faculty

William W. Bannister, *Professor;* B.S., Ph.D., Purdue University.
Alexandre Blumstein, *Professor;* B.S., Sorbonne, France; Ph.D., University of Strasbourg, France.
Rita B. Blumstein, *Professor;* B.S., Sorbonne, France; Ph.D., University of Delaware.
Stuart B. Clough, *Professor;* B.S., University of Massachusetts; M.Ch.E., University of Delaware; Ph.D., University of Massachusetts.
Martin Isaks, *Associate Professor;* B.S., Purdue University; M.S., Iowa State University; Ph.D., University of Cincinnati.
Stanley C. Israel, *Professor;* B.S., Parsons College; Ph.D., Lowell Technological Institute.
Edwin Jahngen, *Associate Professor;* B.S., Bates College; Ph.D., University of Vermont.
Albert D. Kowalak, *Associate Professor;* B.S. College of William and Mary; M.S., Ph.D., Virginia Polytechnic Institute.
Kuang-Pang Li, *Associate Professor;* B.S., M.S., National Taiwan University; M.S., Ph.D., University of Illinois.
Irving Lipschitz, *Associate Professor;* B.A., M.S., New York University; Ph.D., Virginia Polytechnic Institute.
Kenneth A. Marx, *Assistant Professor;* B.S., California State University at San Diego; Ph.D., University of California, Berkeley.
James B. Pierce, *Professor;* B.S., Thiel College; M.S., Ph.D., Case Institute of Technology.
Chong Wha Pyun, *Professor;* B.S., M.S., Seoul National University, Korea; Ph.D., Brown University.

Harry Rubinstein, *Professor;* B.S., Brooklyn College; Ph.D., Purdue University.
Joseph C. Salamone, *Professor;* B.S., Hofstra University; Ph.D., Polytechnic Institute of Brooklyn.
Samuel P. Sawan, *Professor;* B.S., Ph.D., University of Akron.
Terrance Tougas, *Assistant Professor;* B.S., S.U.N.Y. Plattsburg; Ph.D., University of Massachusetts, Amherst.
Shan S. Wong, *Professor;* B.S., Oregon State University; Ph.D., Ohio State University.

Master of Science Degree Program

This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

Diagnostic-Evaluation Examinations

During the week of registration, each entering student must present him/herself for written examinations in four fields: organic, physical, inorganic and analytical chemistry. The examinations are the ACS Graduate Level Placement Exams and are used to help plan the student's program.

Credit Requirements

Of the 18 credit minimum, exclusive of research and seminar, required in listed subjects, a minimum of 15 credits must be taken in chemistry. The remaining course credits (3 or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry except for those designated in the catalog or approved by a student's adviser. Each graduate program in chemistry must include at least three advanced subjects from three of the following areas: Organic Chemistry, Inorganic Chemistry, Analytical Chemistry, Physical Chemistry, Biochemistry or Polymer Chemistry, unless such requirements have been met previously. Depending upon student's performance on the diagnostic examinations, the student's advisory committee may recommend that the student take additional courses in the areas of deficiency.

Although the design of the student's program is the responsibility of his Advisory Committee, the following listing provides a suggested core of offerings:

Chemistry - *First Semester Courses Offered*		
84-515	Practicum in Chemical Literature	(1-2)2
84-523	Organic Reaction Mechanisms	(3-0)3
84-526	Theory and Applications of Chromatography	(3-0)3
84-532	Advanced Physical Chemistry	(3-0)3
84-550	Biochemistry I	(3-0)3
84-601	Chemistry Seminar	(1-0)1
84-603	Chemistry Colloquium	(1-1)1
84-651	Selected Topics in Chemistry	(3-0)3
84-701	Graduate Research in Chemistry	(0-9)3
Chemistry - *Second Semester Subjects*		(3-0)3
84-514	Advanced Analytical Chemistry	(1-6)3

84-516	Advanced Laboratory Techniques	(3-0)3
84-519	Environmental Chemistry	(3-0)3
84-514	Organic Synthesis	(3-0)3
84-543	Advanced Inorganic Chemistry	(3-0)3
84-551	Biochemistry II	(3-0)3
84-568	Structural Analysis	(3-0)3
84-602	Chemistry Seminar	(1-0)1
84-604	Chemistry Colloquium	(1-0)1

Language Requirements
There is no language requirement for the M.S. degree in Chemistry.

Thesis Examination
Each candidate for the Master of Science degree in Chemistry must appear for an oral examination in the field of his/her thesis before an examining committee appointed by the Department Chairperson from the graduate faculty in Chemistry. This examining committee normally will include the student's Advisory Committee plus an additional member of the graduate faculty. The chairperson for the examination shall be the research adviser. While only members of the examination committee and the Dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester of study. Application to take the examination must be filed by the student with the Department Chairperson at least one month prior to the close of the last semester. Each student has the right to one re-examination within the period of one year.

Doctor of Philosophy Degree Program
The doctoral program in chemistry is designed to provide the student with a background in advanced course work and chemical laboratory techniques that will prepare him or her to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program
The doctoral degree normally requires four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through a conference with the Advisory Committee (or with his or her temporary adviser).

All students entering the doctoral program must take the complete set of evaluation examinations given during the week of registration as described in the section relating to the Master of Science program in Chemistry.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. The first year is usually given to subjects in the major branches of chemistry in preparation for area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration.

The second and final part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to begin research as early as possible in the program of study.

Language Requirements
Students must demonstrate satisfactory reading ability in one foreign language (level two), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the student's Advisory Committee and approved by the Department.

Credit Requirements
Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least 18 to be taken in chemistry. The remaining course credits (9 or more, with a student's Advisory Committee having the authority to add 6 additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirements. Planning the program of courses with the student is the responsibility of a student's Advisory Committee.

Written Area Examinations
Upon admission to the Ph.D. program the student must pass exams in his/her major area of specialization. The method of conducting these area exams is decided by the staff in each field of specialization. Analytical majors take six cumulative examinations, each of which focuses on a given area of analytical chemistry. Organic majors take a series of cumulative exams which are designed to test the student's ability to handle information. A student is given eight chances to pass four examinations with a mark of pass or fail given for each examination. Students must take the examinations consecutively.

Research Proposition
As part of the area examination(s) a Ph.D. candidate must present an oral defense of an original research proposal. With the aid and advice of the Advisory Committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty members in attendance. It is taken by the end of the semester following completion of area exams.

Chemistry Seminar
During each year of residence the student is required to attend and to participate in 84-601-602, Chemistry Seminar, (1-0)(1-0)2 and 84-603-604 Chemistry Colloquium, (1-0)(1-0)2.

Course Offerings and Distribution

As a basis for the candidacy examinations the following core courses are recommended for the first-year students in the doctoral program:

84-532	Advanced Physical Chemistry	(3-0)3
84-514	Advanced Analytical Chemistry	(3-0)3
84-515	Practicum in Chemical Literature	(1-2)2
84-516	Advanced Laboratory Techniques	(1-3)2
84-523	Organic Reaction Mechanism and Structure	(3-0)3
84-524	Organic Synthesis	(3-0)3
84-543-544	Modern Inorganic Chemistry	(3-0)(3-0)3

Each student in the Ph.D. program shall take both Advanced Physical Chemistry and Advanced Organic Chemistry and two courses from Advanced Inorganic, Advanced Analytical, Biochemistry, or Polymer Chemistry unless such requirements have been met previously.

If the results from the diagnostic examinations indicate adequate background in any of the above subjects, substitution by a more advanced subject in the 500 series is recommended.

Additional subjects in chemistry or in the field of the minor may be taken in the first year if desired, provided the prerequisites are met.

In the second year, subjects supporting concentration in specific fields are available as follows:

Analytical Chemistry

84-519	Environmental Chemistry	(3-0)3
84-526	Theory and Applications of Chromatography	(3-0)3
84-528	Electroanalytical Chemistry	
84-529	Chemometrics	
84-568	Structural Analysis	(3-0)3
84-585-586	Nuclear and Radiochemistry	(3-4)4,(3-4)4

Organic Chemistry

84-521	Physical Organic Chemistry	(3-0)3
84-527	Stereochemistry	(3-0)3
84-561	Advanced Organic Synthesis	(3-0)3
84-563	Chemistry of Natural Products	(3-0)3
84-565	Heterocyclic Chemistry	(3-0)3
84-568	Structural Analysis	(3-0)3

Physical Chemistry

84-531	Statistical Thermodynamics	(3-0)3
84-534	Quantum Chemistry	(3-0)3
84-535-536	Advanced Topics in Physical Chemistry	(3-0)(3-0)6
84-540	Chemical Kinetics	(3-0)3

Biochemistry

84-550-551	Biochemistry	(3-0)(3-0)6
84-538	Biochemical Mechanisms	(3-0)3

84-554	Techniques in Biology	(1-5)2
84-563	Chemistry of Natural Products	(3-0)3
84-651	Selected Topics in Biochemistry	(3-0)(3-0)6

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1. Complete the first year's core of recommended subjects and have a satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. Pass the area examinations which includes completion of research proposal.
3. Fulfill the language requirements.
4. Secure the approval of the Advisory Committee and the Department Chairperson.

When these requirements have been fulfilled, the Department Head notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

84-513 Spectroscopy **(3-0)3**

Prerequisite: 84-431-432 or equivalent

A presentation of molecular spectra and molecular structure is given to illustrate the empirical results and the theoretical backgroud necessary to interpret the results.

84-514 Advanced Analytical Chemistry **(3-0)3**

Prerequisite: 84-313 and 314 or permission of Analytical Chemistry Faculty

This course is required of all students in the Analytical Chemistry and Ph.D. Environmental Studies Program. Principles of modern atomic spectroscopy, various separation methods and electroanalytical chemistry are covered. The course is designed to prepare a student for advanced courses in the area of coverage.

84-515 Practicum in Chemical Literature **(1-2)2**

Prerequisite: Permission of Instructor

Use of the chemical library, journals, reference works and other technical publications pertaining to chemical subjects. Exercises in finding, assembling and using such data. The student will be expected to assimilate the use of automated information retrieval and conduct computer assisted literature searches.

84-516 Advanced Laboratory Techniques **(1-6)3**

Prerequisite: Permission of Instructor

A study of the theory and application of the more advanced techniques and equipment in the preparation and purification of organic compounds, including high efficiency fractionation, vacuum and molecular distillation, hydrogenation and reactions in inert atmosphere.

84-517 Glass Working **(1-0)1**

Prerequisite: Permission of Instructor

Fundamental techniques in the preparation and assembling of glass apparatus.

84-519 Environmental Chemistry (3-0)3

Prerequisite: Permission of Instructor

The chemistry of the oceans, atmosphere and biosphere source and removal mechanisms of natural and anthropogenic substances, thermodynamic and kinetic models in addition to instrumental analytical methods.

84-521 Physical Organic Chemistry (3-0)3

Prerequisite: 84-523-524 or equivalent

Modern and classical methodology in the study of organic reactions. Linear free energy relationships, tracer methods, orbital symmetry and other selected topics will be covered.

84-523 Organic Reaction Mechanisms and Structures
For graduate students only (3-0)3

Designed to provide insight into how reactions occur and how the reactions mechanism is studied. Emphasis is placed on bonding, substitution and elimination processes, stereochemistry, and conformational analysis.

84-524 Organic Synthesis
For graduate students only (3-0)3

Mechanism, scope and limitations of important selected types of reactions, and designs of synthetic sequences. Emphasis is placed on reduction, oxidation, halogenation, alkylation, and acylation reactions.

84-526 Theory and Applications of Chromatography (3-0)3

Prerequisite: Permission of Instructor

Coverage directed to the performance of packed and capillary column for gas chromatography and HPLC. Modern injection, detector and pumping systems used in chromatography are also discussed.

84-527 Stereochemistry (3-0)3

The fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

84-528 Electronanalytical Chemistry (3-0)3

This course is an introduction to the theory and application of electroanalytical chemistry. It includes a discussion of electrode processes, electroanalytical techniques and electrochemical instrumentation.

84-529 Chemometrics (3-0)3

This course is a presentation of mathematical techniques useful for evaluating chemical data. Topics addressed include: parametric statistics, ANOVA, regression analysis, optimization and pattern recognition.

84-531 Statistical Thermodynamics (3-0)3

Prerequisite: 84-432 or equivalent

Fundamentals of equilibrium statistical mechanics, classical and quantum statistics. Molecular theories of gases, crystals and liquids, with emphasis on chemical aspects. Electrolyte and non-electrolyte solutions, polymer and polyelectrolyte systems, chemical equilibria and reaction rate processes.

84-532 Advanced Physical Chemistry (3-0)3

Prerequisite: Permission of Instructor

Extension of introductory physical chemistry. Open to seniors and first-year graduate students in chemistry and related fields. Emphasis is placed on quantum chemistry of atoms and molecules as well as on classical and statistical thermodynamics.

84-534 Quantum Chemistry (3-0)3

Prerequisite: 84-431 or equivalent

Principles and methods of quantum mechanics with special attention to chemical applications, such as electronic nature of atoms and molecules, vibrations and rotation of molecules, and interaction of radiation with matter.

84-535-536 Advanced Topics in Physical Chemistry **(3-0)(3-0)6**
Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

84-538 Biochemical Mechanisms **(3-0)3**
Prerequisite: 84-422-523 or permission of instructor
Selected biochemical reactions will be presented from the point of view of organic reaction mechanisms. Kinetics, coenzyme and enzyme catalysis and mechanisms of oxidative phosphorylation will be emphasized.

84-540 Chemical Kinetics **(3-0)3**
Prerequisite: 84-432 or equivalent
The theoretical and empirical treatment of chemical kinetic data as well as the methods of obtaining these data. Determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanism, collision theory, and absolute rate theory.

84-543 Modern Inorganic Chemistry **(3-0)3**
Prerequisite: Permission of Instructor
Similar to 84-443-444 but designed specifically for graduate students. Emphasis is placed on the theory of the chemical bond, bonding in complexes, coordination theory, spectroscopic methods, non-aqueous solvent systems.

84-544 Chemical Applications of Group Theory **(3-0)3**
Prerequisite: 84-334, 84-543 or equivalent
Properties of groups as applied to chemical systems. Development of the ligand field theory and prediction of electronic and vibrational-rotational spectra.

84-563 Chemistry of Natural Products **(3-0)3**
Prerequisite: 84-568, 84-311 or equivalent
An advanced subject covering the proof of structure of various types of natural products, approaches to the total synthesis of some and also the biosynthetic pathways.

84-565 Heterocyclic Chemistry **(3-0)3**
Prerequisite: Permission of instructor
Classification, nomenclature, structure, synthesis and utility of the more important classes of heterocyclic compounds.

84-568 Structural Analysis **(3-0)3**
Prerequisite: Permission of instructor
Practical application of instrumental data in the determination of the structure of organic compounds. Includes mass spectroscopy, ultraviolet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy.

84-585 Nuclear and Radiochemistry **(3-0)3**
Prerequisite: Permission of Instructor
This course stresses the fundamentals of radioactivity, atomic nuclei, nuclear reactions, reactors and detection and measurement of radiation. Applications of material and anthropogenic radioactive tracers to oceanic and atmospheric studies are also presented.

84-601,602 Chemistry Seminar **(1-0)(1-0)2**
Required of all graduate students
Presentation of current topics by graduate students.

84-603-604 Chemistry Colloquium
Required of all graduate students (1-0)1
Presentation of current topics by visiting scientists and staff.

84-651 Selected Topics in Chemistry (3-0)3
Prerequisite: Permission of instructor
Advanced topics in various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

84-701 Graduate Research in Chemistry (0-9)(0-9)6
An independent investigation of a problem by the student in conference with a faculty adviser and approved by the Department Chairperson. A clear and systematic written presentation of the results is required.

84-751 Advanced Projects in Chemistry (0-3)(0-3)2
Special projects laboratory undertaken by a student to expand his or her knowledge in specific fields not necessarily related to his or her thesis. Content of project and hours assigned must be approved by the Department Chairperson.

POLYMER SCIENCE (Department of Chemistry)

Master of Science in Polymer Science

The Polymer Science Program of the Department of Chemistry offers the student a unique opportunity for advanced study and research training in the rapidly growing field of macromolecular science. Provision is made to include the broadest coverage of both practical and theoretical aspects of polymer science, taking advantage of the unique facilities at the University of Lowell in chemistry of macromolecules, plastics engineering and other related fields.

Diagnostic-Evaluation Examinations

During the week of registration each entering student must take written examinations in the fields of organic, physical and analytical chemistry. An evaluation examination in polymer science is offered to those who wish to be exempted from 97-503-504. Except for polymer science, the examinations are the ACS Graduate Level Placement Exams.

Course Requirements

A candidate for the Master of Science Degree in Polymer Science must have a minimum of 18 credit hours of course work, exclusive of research and seminar, as well as complete a thesis based upon original research. Of the credit requirement, a minimum of 15 credits must be taken in the Department of Chemistry. The remaining course credits (3 or more) may be taken in chemistry (polymer science) or in such related fields as plastics, physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry, except for those so designated in the catalogue or approved by a student's adviser. All students must take 97-601-602, Polymer Science Seminar and 97-603-64, Polymer Science Colloquium each year they are in residence. The first semester of Polymer Science Seminar and Colloquium may be given concurrently with the first semester of Chemistry Seminar and Colloquium.

Although the design of the academic program is the responsibility of the student's Advisory Committee, the following listing provides a suggested core of subjects for program development.

First Semester Subjects

97-503	Advanced Polymer Science I	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
97-511	Biopolymers	(3-0)3
97-553	Organic Chemistry of Macromolecules	(3-0)3
97-601	Polymer Science Seminar	(1-0)1
97-701	Graduate Research in Polymer Science	(0-9)3
84-532	Advanced Physical Chemistry	(3-0)3
84-523	Organic Reaction Mechanisms and Structure	(3-0)3

Second Semester Subjects

97-504	Advanced Polymer Science II	(3-0)3
97-506	Polymer Preparation and Characterization II	(4-0)1
97-512	Properties of Bulk Polymers	(2-0)2
97-602	Polymer Science Seminar	(1-0)1
97-702	Graduate Research in Polymer Science	(0-0)3
84-434	Colloid and Surface Chemistry	(3-0)3
84-524	Organic Synthesis	(3-0)3
26-523	Plastics Processing Techniques	(1-2)2

Language Requirements

There is no foreign language requirement for the master's degree in Polymer Science.

Thesis Examination

Each candidate for the master's degree must appear for an oral examination in the field of polymer science before an examining committee appointed by the Department Chairperson from the graduate faculty in the Department of Chemistry. The examining committee will include the student's Advisory Committee plus an additional graduate faculty member. The chairman for the examination shall be the student's thesis adviser. While only members of the examination committee and the Dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Applications to take the examination must be filed by the student with the Chairman of the Department of Chemistry at least one month prior to the close of the last semester.

Ph.D. - POLYMER SCIENCE/PLASTICS EGNINEERING OPTION

An Interdisciplinary Program

Students in the Ph.D. Program in the Department of Chemistry may elect the Polymer Science/Plastics Engineering Option. This doctoral program is

organized jointly with the Department of Plastics Engineering. The program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knowledge in the fields of macromolecules or plastics.

Plan of Program
The doctoral degree normally requires four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary adviser).

All students entering the program must take the ACS Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503-504.

Requirements for Admission
Requirements for admission into the program are the same as those for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Undergraduate deficiencies in the student's background must be remedied promptly, usually by the end of the student's second semester. During this period, the student must also successfully complete graduate courses appropriate to his/her background. Students will not be formally admitted to the Ph.D. program if their grade point average is below B.

Advisory Committee
Upon admission the student will be assigned a temporary adviser by the Coordinators of the Graduate Polymer Program and Graduate Plastics Program.

The student's major thesis adviser will become the chairperson of the permanent Advisory Committee and will also be responsible for funding of the research.

For students who elect the Plastics concentration, the permanent Advisory Committee will be composed of four members, two from the Department of Chemistry and two from the Department of Plastics Engineering. One of the committee members from the Chemistry Department will have the responsibility of advising the student in course work and research activities in the field of polymers.

The Advisory Committee will meet at least once each semester to monitor the progress of the student's research.

Program Outline
The initial part of the program (the first two years) is devoted to formal course work. The first year usually is given to subjects in major branches of chemistry, polymers, and plastics in preparation for the student's area

(candidacy) examinations. The second year is devoted primarily to advanced subjects in areas relating to Polymers and Plastics.

The second part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to start research as soon as possible. The student's thesis (dissertation) adviser will be responsible for funding of the research.

Language Requirements

The student must demonstrate satisfactory reading ability in one foreign language (Level Two), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the student's Advisory Committee and approved by the department.

Written Area Examinations

Upon formal admission to the Ph.D. program the student must pass cumulative area examinations. The examinations must be taken within one semester of finishing the formal course work and must be taken consecutively.

Each student must also present an oral defense of an original research proposal by the end of the semester following completion of the area exams.

Course Requirements

Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least four courses to be taken in Chemistry and Polymer Science (84 and 97 prefixes). The remaining course credits may be taken in Chemistry or in the courses listed below. Credit normally is not allowed for undergraduate subjects in Chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a Student's Advisory Committee and must include advanced subjects in the appropriate areas of Chemistry, Polymers, and Plastics. When it is necessary to carry less than the normal credit load of 9 per semester, the student must apply to the chairman of the department through the chairman of his/her Advisory Committee for approval.

Required Courses

The student must take the following core courses:

84-523	Organic Reactions	(3)
	or	
84-568	Structural Analysis	(3)
84-531	Advanced Physical Chemistry	(3)
97-503	Advanced Polymer Science I	(3)
97-504	Advanced Polymer Science II	(3)
97-505	Polymer Preparation & Characterization I	(1)
97-506	Polymer Preparation & Characterization II	(1)
97-512	Bulk Properties of Polymers	(3)
	or	
25-503	Mechanical Behavior of Polymers	(3)

26-506	Polymer Structure	(3)
26-509	Plastics Processing Theory	(3)
26-510	Plastics Processing Theory	(3)

In addition, the student must take 84-515 (Chemical Literature 2 credits) and must register for Polymer Seminar 97-601-602 and 97-603-604 Polymer Science Colloquium each semester.

The remaining formal course credits may be chosen from the following (other courses may be used with permission of the Dissertation Committee):

97-511	Biopolymers	(2)
97-553	Organic Chemistry of Macromolecules	(2)
84-434	Colloid and Surface Chemistry and Its Environmental Applications	(3)
97-549	Physical Chemistry of Macromolecules I	(3)
97-550	Physical Chemistry of Macromolecules II	(3)
26-502	New Plastics Processing Techniques	(3)
26-504	Processing, Morphology, and Properties	(3)
26-507	Plastics Industry Organization	(3)
25-512	Plastics Foams	(3)
26-513	New Plastics Materials	(3)
26-516	Composite Materials	(3)
26-518	Product Design	(3)
26-521	Polymerization Engineering	(3)
26-523	Material & Energy Balances in Plastics Processing	(3)
26-531	Survey of Synthetic Fibers & Fiber Structures	(3)
26-532	Adhesives and Adhesion	(3)
26-533/4	Coatings Science and Technology	(3)(3)
26-535	Rubber	(3)
26-536	Rheology in Polymer Processing	(3)
26-537	Engineering Properties of Plastics	(3)
26-543	Survey of Plastics Materials	(3)
26-544	Survey of Plastics Processing	(3)

Courses of Study (Department of Chemistry)

97-503 Advanced Polymer Science I **(3-0)3**

Prerequisite: Permission of Instructor

Introduction to chain statistics and thermodynamics of macromolecular solutions, methods of study of molecular weight and chain conformation, and the properties of polymers in bulk including viscoelasticity and crystallinity.

97-504 Advanced Polymer Science II **(3-0)3**

Prerequisite: Permission of Instructor

A study of the principles of condensation, free radical, ionic, coordination and ring-opening

polymerization. The topics include the effect of polymerization techniques on reaction kinetics and molecular weight, and the evaluation of reactivity ratios in copolymerization reactions.

97-505 Polymer Preparation and Characterization I **(0-4)1**
Prerequisite: Permission of Instructor
A laboratory course designed to acquaint the graduate student with the techniques used in the synthesis and characterization of macromolecules.

97-506 Polymer Preparation and Characterization II **(0-4)1**
Prerequisite: Permission of Instructor
An advanced laboratory in polymer science concerned with the instrumental study of macromolecules by utilization of osmometry, light scattering, gel permeation chromatography, vapor pressure osmometry and infrared spectroscopy.

97-511 Biopolymers **(3-0)3**
Prerequisite: Permission of Instructor
Conformation and configuration of vinyl polymers and polypeptides. Helix-coil transitions in proteins and polypeptides. Biological specificity and macromolecular structure. Synthesis of stereoregular polypeptides. Structure and physical properties of nucleic acids.

97-512 Properties of Bulk Polymers **(3-0)3**
Prerequisite: Permission of Instructor
Structure and properties of bulk polymers in the glassy, rubbery, and crystalline states. Topics covered include chain statistics, rubber elasticity, crystalline polymers, glass transition, segmental motion and viscoelasticity.

97-549 Physical Chemistry of Macromolecules I **(3-0)3**
Prerequisite: 97-503 or equivalent
Physical chemistry of polymers, including structure and conformation, chain statistics, molecular weight distributions and averages, polymerization kinetics and classical and statistical thermodynamics of polymer solutions.

97-553 Organic Chemistry of Macromolecules **(3-0)3**
Prerequisite: 97-503, 504
An advanced study in polymer science concerned with the synthesis of macromolecules and their mechanisms of formation.

97-602 Polymer Science Seminar **(1-0)1**
Required of all Polymer Science graduate students
Presentation of current topics in polymer science by graduate students.

97-603-604 Polymer Science Colloquium **(1-0)1**
Required of all Polymer Science graduate students. Presentation of current topics in polymer science by visiting scientists and staff.

97-651 Selected Topics in Polymer Science **(3-0)3**
Prerequisite: Permission of Instructor
Advanced topics in various aspects of polymer science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge in the field of macromolecules.

97-701 Graduate Research in Polymer Science **(0-9)3**
An independent investigation of a problem by the student in conference with a polymer science faculty adviser and approved by the Department Chairperson. A clear and systematic written presentation of the results is required.

97-751 Advanced Projects in Polymer Science **(0-3)1**
Special projects undertaken by a student to expand knowledge in a specific field not necessarily

related to the thesis. Content of project and hours assigned must be approved by the Department Chairman.

Candidacy for the Doctorate in Chemistry

To be admitted for candidacy for the doctorate, a student must:

1. Complete a first year's core of recommended subjects and have a satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. Complete the course credit requirements.
3. Pass the area examinations which includes completion of research proposal.
4. Fulfill the language requirements.
5. Secure the approval of his/her Advisory Committee and the Graduate Coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the Graduate Coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admisson to candidacy in no way guarantees the granting of the degree.

Ph.D. - OPTION IN ENVIRONMENTAL STUDIES

An Interdisciplinary Program

This graduate program is designed to meet the need for Ph.D.'s who will have experience in various areas of environmental research. The candidates in this program will have available to them courses and faculty not only in Chemistry, but also Physics, Biology, Civil Engineering and Chemical Engineering. The combination of faculty with a variety of research expertise gives this program unique characteristics and affords the student the opportunity to perform practical interdisciplinary research. It is expected that most students will require at least four years beyond the Bachelor's and two years past the Master's degrees.

Entrance Requirements

The applicant will have an earned bachelor's degree in one of the following fields: Chemical or Civil Engineering, Biology, Environmental Sciences, Geology or Physics. Students will be expected to have satisfactorily completed undergraduate courses in analytical, organic and physical chemistry. However, applicants who have not completed courses in these areas of chemistry may remedy their deficiencies during the first year of graduate study and, therefore, are encouraged to apply. Admissions will be determined by committee based on grade point average and recommendations. The student who is accepted into the program will be required to take A.C.S. Diagnostic Examinations prior to the first semester of graduate study to determine if any deficiences exist in the appropriate areas. An entering graduate student in the program who has enrolled in the appropriate undergraduate course to satisfy a deficiency will be exempt from taking that particular diagnostic examination.

Program Outline

A total of 45 credits are required for the Ph.D. program. Of these, at least 27 credits must be in course work and the rest is usually in thesis research. Of the 27 course credits 18 must be in the required courses shown below and at least 15 credits must be in chemistry (Prefix 84).

After the first year of study the student must have a 3.2 cumulative average with no grade below a BC. In addition, the student will register for chemistry departmental seminar each semester the student is in residence.

Required Courses:

84-514	Advanced Analytical Chemistry	(3-0)3
84-532	Advanced Physical Chemistry	(3-0)3
84-523	Organic Reaction Mechanism - *or*	(3-0)3
84-568	Structural Analysis	(3-0)3
18-522	Municipal, Industrial and Hazardous Waste Management	(3-0)3
14-561	Physical Chemical Treatment Processes	(3-0)3
14-567	Environmental Chemistry I	(3-0)3

Elective Course Offerings

Listed below are some of the elective courses which are currently being offered:

84-519	Environmental Chemistry	(3-0)3
84-526	Chromatography	(3-0)3
84-560	Structural Analysis	(3-0)3
98-503	Radiation Biology	(3-0)3
14-561	Physical Chemical Treatment Processes	(3-0)3
18-527	Environmental Law	(3-0)3
81-510	Limnology	(3-0)3
84-585/6	Nuclear Chemistry	(3-0)3
18-510	Water Resources Management	(3-0)3
18-523	Air Resources Management	(3-0)3
18-525	Epidemiology for Environmental Studies	(3-0)3
14-565	Industrial Waste Treatment Processes	(3-0)3

Language Requirements

The student must demonstrate satisfactory reading ability in one foreign language (Level Two), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the Student Advisory Committee and approved by the department.

Written Area Examinations

Upon formal admission to the Ph.D. program the student must pass cumulative area examinations on environmental topics. The examinations must be taken within one semester of finishing the formal course work and must be taken consecutively.

Each student must also present an oral defense of an original research proposal.

Facilities
The research laboratories are housed in the Olney, Olsen and Engineering Buildings. Available for use by students: 60 and 100 MHz NMRs, gas chromatography-mass spectrometry, various gas chromatographs and HPLC instrumentation, infrared and UV-visible, fluorescence, atomic absorption/emission spectro-photometers including Perkin Elmer 403 and 4000 equipped with graphite furnaces, spark source mass spectrometry, inductively coupled plasma emission spectrometer and various electrochemical instrumentation.. The Pinanski Building houses our 5.5 MeV Van de Graaff Accelerator, a 1 megawatt research reactor utilized for neutron activation analysis and several radiochemical laboratories.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM (Biochemistry Option)

The Department of Chemistry and the Department of Biological Sciences have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. This program draws upon the special and diverse talents of both faculties, and provides students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Admission Requirements and Removal of Undergraduate Deficiencies
Admission to the program requires demonstration of an acceptable B.S., B.A., or M.S. degree in chemistry, biology, biochemistry or other related science. Students will be expected to have completed two semesters each of General, Organic and Physical Chemistry as well as Introductory Biology. Deficiencies in any of these areas must be removed by enrolling in the corresponding undergraduate course during the first year in the program.

Academic Standards for Retention in the Biochemistry Program
The graduate student is expected to maintain an average of B or better in all his/her graduate-level courses. If at any time a student earns two C's or BC's, or any grade lower than C, actions such as warning, probation, loss of degree candicacy, etc. will be taken by the Biochemistry Program Committee.

Language Requirements
A dictionary reading knowledge of one of the three languages, German, Russian or French is required. However, this must not be the student's native tongue. The language requirement may be satisfied by any one or combination of the three options:

a. By passing an examination given by the Graduate Committee of the Chemistry Department.
b. By transferring from another institution a year course with B or better grade beyond the first year.
c. By passing with a grade of B or better the language courses: French 50-103, 50-104; German 51-113, 51-114; Russian 53-113, 53-114.

In addition, the student must acquire facility in one additional tool. This may be a second language, computer programming, statistics, advanced mathematics or other skills appropriate to the student's area of research.

Degree Requirements
A minimum of 45 credits beyond the Bachelor's Degree level are required in coursework exclusive of thesis and seminar. Eighteen of these credits are in Chemistry/Biochemistry core courses (lists A and B). The remaining nine may be selected from any Chemistry Department graduate courses, or approved biochemistry electives offered by the Department of Biological Sciences (lists C and D).

A. **Required Courses** *(12 credits):*

			Credits
84-538		Biochemical Mechanisms	3
84-550	(81-550)	Biochemistry I	3
84-551	(81-551)	Biochemsitry II	3
84-554	(81-554)	Techniques in Biochemistry	2
84-555	(81-555)	Special Techniques in Biochemistry	1

B. **Prescribed Electives:** A minimum of six credits must be selected from the following list:

84-523	Organic Reaction Mechanisms and Structure	3
84-527	Stereochemistry	3
84-532	Advanced Physical Chemistry	3
84-568	Structural Analysis	3

C. **Electives:** A minimum of six credits may be selected from any Chemistry Department graduate courses and/or the following approved biochemistry courses offered by the Department of Biological Sciences:

81-503	Biochemistry of Metabolic Disorders	3
81-529	Biochemical Aspects of Heart Disease	3
81-565	Biochemistry of Micronutrients	3
81-567	Recombinant DNA Techniques	3
81-569	Recombinant DNA Laboratory	1
81-576	Cell Culture and Hybridoma	2
81-578	Cell Culture and Hybridoma Laboratory	1
81-585	Eukaryotic Gene Expression	3

D. **Additional Electives:** A minimum of three credits must be selected from any of the graduate courses offered by the Department of Chemistry or the Department of Biological Sciences.

Seminars
During each semester in residence all full-time students must register for a one-credit seminar course. The student is expected to prepare two one-hour presentations during his/her residence, and to attend one seminar each week, as required by the Chemistry Department.

Journal Club
Once admitted to candidacy for the Ph.D. (generally at the end of the second year) each student will participate in a journal club to discuss recent articles from assigned journals.

Research
A. *Initiation of Research - Preceptor Selection Procedure*
The dissertaton research of each graduate student may be initiated at any time but not later than the end of the second semester in the program. The student is advised to make serious efforts, prior to the summer following his/her first entrance to the program, to initiate faculty research interviews and attempt to identify the area of his/her research interest and particular research group which may be suitable for pursuing his/her research goals.

B. *Advisory Committee*
After the student has chosen his/her research preceptor, an Advisory Committee will be appointed to monitor the progress of the student's research at least twice a year. It is the student's responsibility to submit a typewritten semi-annual progress report to the Advisory Committee with a copy forwarded to the Biochemistry Program Committee. The due dates of such reports are January 1 and July 1 of each year. The advisory committee will be a permanent part of the student's examination committees.

Examinations
A. *Qualifying Examination*
If the average letter grade for Biochemistry I and II is less than 3.0, the student is required to pass an oral examination in biochemistry administered by the Biochemistry Program Committee. Incoming students wishing to receive credit for an undergraduate biochemistry course may also be requested to pass this examination. Petition to take the examination may be made to the Biochemistry Program Curriculum Committee. Failure to achieve either the necessary letter grade average in Biochemistry I and II or a passing grade on the Qualifying Examination will be reason for review of the candidate's status in the program. The student will be advised either to withdraw from the program or to take the examination again.

B. *Comprehensive Examination*
Part 1. **The cumulative examination**
Ten cumulative examinations will be offered during the academic year, each worth 10 points. The subject material for these exams will be announced at least 2 weeks in advance of the exam date. To satisfy the requirements, each student must score a total of 50 points by the end of their second year in residence. Any student failing to do so may petition to the Program Committee for an extension which will consist of the next 10 consecutive exams. Denial of this petition of failure by the student to acquire 50 points in the next 10 consecutive exams will mean termination from the program with the award of an M.S. degree (assuming that all requirements for that degree have been completed). The student

may apply for re-entry into the Ph.D. program after successful completion of the M.S. program.

Part 2. **Non-thesis research proposal**
Within six months of satisfying the cumulative exam requirement, the student will be required to present and defend, orally, a research proposal in an area of biochemistry other than that of his/her thesis. An outline of the proposed research will be distributed to the Examination Committee at least one week prior to the examination.

The examining committee will be composed of the student's Advisory Committee and three additional faculty members chosen after consultation of the student with his/her preceptor. The student should consult his/her preceptor in establishing this committee. All members of the University Community are welcome to attend these examinations.

Admission to Candidacy for the Doctorate
To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average.
2. Pass the General Examination and, if necessary, the qualifying examination.
3. Fulfill the language requirement (as outlined by the Chemistry Department).
4. Secure approval of his/her research preceptor and the biochemistry committee.

When these requirements have been fulfilled, the Biochemistry Program Curriculum Committee will recommend that the graduate coordinator of the Department of Chemistry notify the Dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

84-538 Biochemistry Mechanisms **(3-0)3**
Prerequisites: 84-551 or Permission of Instructor
Discussion of various biochemical reactions from the point or view of organic reaction mechanisms. Kinetics, coenzymes and methods of study of enzyme catalysis and mechanisms will be emphasized.

84-550 Biochemistry I **(3-0)3**
Prerequisite: 84-222 or 84-224, 84-335 or 84-344 or
Permission of Instructor
An advanced study of the structure and properties of proteins, nucleic acids, carbohydrates and lipids, including kinetics and mechanisms of enzyme action, and detailed description of metabolic pathways of carbohydrates and lipids.

84-551 Biochemistry II **(3-0)3**
Prerequisite: 84-550 or Permission of Instructor
A continuation of 84-550 with emphasis on metabolic pathways of amino acids and nucleic acid, biosynthesis of proteins and selected topics in molecular biology and various areas of biochemistry.

81-552 Recombinant DNA Techniques **(3-0)3**
Prerequisites: 81-335 and Biochemistry
A study of the principles and specialized techniques of purifying, manipulating, and cloning of recombinant DNA molecules. Includes techniques involving restriction endonuclease mapping of genomes, cloning of DNA fragments from procaryotic and eucaryotic genomes, types of vectors used in genetic engineering, and the applicability of these techniques to solution of various problems in cell biology.

81-553 Laboratory Techniques and Instrumentation **(1-6)3**
A course designed to acquaint the student with a variety of research techniques and instrumentation used in the biological laboratory, their theory and practical applications.

84-554 Techniques in Biochemistry **(1-5)2**
Prerequisite: 84-550 or Permission of Instructor
Laboratory experiments designed to acquaint the student with modern techniques in biochemistry including protein purification, HPLC, NMR electrophoresis, UV-visible spectrophotometry and various types of chromatography.

84-555 Selected Methods Biochemistry
84-554 or Permission of Instructor **(0-3)1**
A continuation of 84-554 to acquaint student with a variety of research techniques and instrumentation in biochemistry their theory and application.

COMPUTER SCIENCE DEPARTMENT

DEPARTMENT CHAIRPERSON: THOMAS COSTELLO, *Professor;* B.S., Boston College; M.A., University of Maryland; Ph.D., University of Maryland.

GRADUATE COORDINATOR: CHARLES STEELE, *Associate Professor;* A.B., A.M., Boston College; M.S.E.E., Northeastern University..

Faculty

Shimshon Berkovits, *Associate Professor;* B.S. , Massachusetts Institute Technology; M.S., University of Chicago; Ph.D., Northeastern.
James Canning, *Assistant Professor;* B.S., University of Maine at Orono; M.S., Iowa State University; Ph.D., Virginia Polytechnic Institute.
A. L. DeCegama, *Adjunct Professor;* B.S., Madrid University; M.S., Carnegie Institute of Technology, Ph.D., Carnegie-Mellon University; M.B.A., Pepperdine University.
Georges B. Grinstein, *Associate Professor;* B.S., City College of New York; M.S., New York University; Ph.D., University of Rochester.
James Harp, *Distinguished Visiting Lecturer;* A.B., M.S., University of California, Berkeley.
Jesse M. Heines, *Assistant Professor;* B.S., Massachusetts Institute of Technology; M.S., University of Maine; Ed.D., Boston University.
Wayne G. Kellner, *Adjunct Associate Professor;* B.S., University of Connecticut; S.M., Sc.D., Massachusetts Institute of Technology.

Byung-Guk Kim, *Assistant Professor;* B.S.E.E., Seoul National University; M.S.E.E., Ph.D., University of Massachusetts.
David Korff, *Professor;* B.A., Harvard University; Ph.D., Brandeis University.
Patrick Krolak, *Professor;* B.S., University of Chicago; M.A., D.Sc., Washington University (St. Louis).
David Landskov, *Assistant Professor;* B.S., University of Mississippi, M.S. University of Mississippi; Ph.D., University of Southwestern Louisana.
Todd Leadbeater, *Instructor;* B.S., University of Vermont; M.S.E., Wang Institute of Graduate Studies.
Robert Lechner, *Professor;* B.S.E.E., M.S.E.E., Carnegie-Mellon University; Ph.D., Harvard University.
John M. Lewis, *Adjunct Assistant Professor;* B.A., Dartmouth College; M.A., Boston College, Ph.D., Yale University.
William Moloney, *Associate Professor;* B.S., M.S., Lowell Technological Institute.
Shahriar Morafaghi, *Assistant Professor;* B.S., University of S. Louisiana; Ph.D., Northwestern University.
Giampiero Pecelli, *Professor;* B.A., Eastern Washington State University; Ph.D., John Hopkins University.
Arthur Poe, *Professor;* B.S., University of Illinois; M.S., Michigan State University, Ph.D., University of Illinois.
Charles T. Ryan, *Jr., Assistant Professor;* B.S., Bridgewater State College; M.S., Ph.D., Northeastern University.
John C. Sieg, *Instructor;* A.B., Dartmouth College; M.S., University of Lowell.
Stuart Smith, *Associate Professor;* B.A., Rutgers-The State University; MFA, Brandeis University; D.Ed., University of Mass/Amherst.
Joseph C. Spicer, *Adjunct Assistant Professor;* B.A., Northeastern University; M.S.E., Wang Institute of Graduate Studies.

THE PROGRAM

1. *Graduate Program Objectives and Intent*

The graduate program is directed toward the goal of producing applied computer scientists of sufficient breadth and sophistication to fill the ever increasing need for leaders and entrepreneurs in this field.

The master's degree program is designed for applicants with bachelor's degrees in computer science or related areas (Electrical Engineering, Mechanical Engineering, Mathematics, etc.) who have exhibited high levels of aptitude and proficiency in computing. The program at the M.S. level features cooperation with allied departments in the Colleges of Pure and Applied Science, Engineering and Management to coordinate course offerings and laboratories. Students with strong interdisciplinary interests such as in computer engineering/architecture (EE/CS), computer graphics/CAD/CAM (ME/EE/CS), artificial intelligence/robotics (ME/EE/Math/CS), data base/decision support (Math/Management/CS) will be encouraged and advised on an individual basis.

The program has strong industrial ties both for a source of ideas, projects, and funds and for guidance on short term and long term directions. Since many students are recruited from local industry and many will seek employment in local industry, an industrial advisory committee aids in achieving these goals.

The Master of Science degree program in Computer Science directs itself to several different audiences, from the professional with extensive industrial experience pursuing a terminal degree, to the recent graduate aiming ultimately for an advanced research degree. In all cases, one of its

major objectives will be to prepare the student for study or a work environment requiring performance at a level above that of the master's degree.

The Computer Science Department, through the generosity of local industry, has substantial computer resources available to support the graduate program. They include a DEC VAX 11/780 with 4Mb memory, 750 MB disk storage, 40 GIGI and 20 VT 100 terminals and a VS 11 workstation; a DEC VAX 11/730 for faculty-graduate research; DEC 11/44, 11/60, two 11/23's, and a collection of personal computers; eleven Data General Micro Nova micro-computer systems; a WANG VS 80 system with eight workstations; various of the preceding systems are networked via an Interlan based Ethernet and DECnet.

The university computer resources are available to the department for courses and research. These include a CDC dual Cyber 730 system supporting over 450 terminals, a Computervision Designer V CAD/CAM System, DEC PDP 11/44 and seven DEC PDP 11/60's and a Hewlett Packard HP 1000; several of these are networked in SYTEK Broadband, DECnet and Ethernet systems.

PROGRAM DESIGN

1. *Admission Standards and Criteria*

Master of Science degree applicants must submit scores from the Graduate Record Examination, and will be required to have an undergraduate degree in computer science, engineering, mathematics or a related science, from an accredited institution. Minimum grade point averages for admission will be determined by the graduate admissions committee in conjunction with the Graduate School admissions office.

To make up any deficiencies, the graduate committee may prescribe special intensive transitional courses or non-credit remedial work based on a student's individual needs.

2. *Relevance of Prior Experience*

It is a policy of the Computer Science graduate committee to seek out qualified applicants from a variety of backgrounds. Computer science graduate students often have academic backgrounds and enter professional career paths that are interdisciplinary in nature. Candidates with other science and engineering training are particularly well prepared for high technology industry careers. They will bring to the graduate student body a heterogeneous mix of undergraduate backgrounds and work experiences.

Prior experience will also be considered as evidence of technical or professional leadership potential when accepting candidates to the graduate program.

3. *Degree Requirements*

Each degree candidate will be required to pass the following minimum number of credits including one major and one minor area:

M.S. Degree Requirements:	
Core Courses	12 credits
Two Areas of Study	6 credits in each
Electives	6 credits
Total for M.S. Degree	30 credits

An optional M.S. thesis can be substituted for at most six credits.

D.Sc. Requirements	
Course work beyond MS degree (including 2 courses in a major area and 2 courses in two minor areas)	18 credits
D.Sc. Thesis	24 credits
Total	42 credits

Admission to candidacy for the D.Sc. degree requires the completion of a M.S. degree (in Computer Science or in a related area, with coursework and experience which are deemed the equivalent of M.S. level preparation in Computer Science) plus successful completion of the departmental qualifying examinations. Details on examination format, syllabi and study guides may be obtained in the department office. In the case of exceptional individuals who have a demonstrated record of achievement in the field of computing, suitable modifications of these requirements may be approved by the Computer Science Department graduate committee.

Having passed the qualifying examination stage, the candidate will choose a faculty member as principal advisor who will guide the candidate in course selection and preparation for a comprehensive examination on the proposed area or areas of thesis investigation, to be administered by a committee named by the department. Preparation of the thesis, which will represent a contribution to the body of knowledge of the discipline or a significant project or implementation, will be directed by the advisor and will be defended before a committee named by the Department.

COURSE DESCRIPTIONS

91-500 Fundamental Models of Computer Science (3-0)3
Mathematical topics necessary for graduate study in Computer Science: review of sets, relations, functions; elementary combinatorics; summation calculus recurrences, generating functions; logic; machines and languages.

91-501 Data Structures and Algorithms (3-0)3
An advanced discussion of data type and structure, assuming prior exposure to the basics; abstract types, lists, trees, graphs; relevant algorithms and their analysis.

91-502 Analysis of Algorithms (3-0)3
Prerequisite: 91-501
Algorithm development and analysis of their time/space costs; sorting, searching and selection; graph algorithms; polynomial, integer and matrix algorithms; Complexity classes; lower bonds; approximation techniques.

91-510 Topics in Computer Science Fundamentals (3-0)3

91-511 Operating Systems Introduction (3-0)3
(not available for credit to Computer Science degree students) models of operating systems; concurrency and parallelism; synchronization; multi-programming; memory and resource management; scheduling; protection; file-structure.

91-512 Systems Programming Introduction (3-0)3
(not available for credit to Computer Science degree students) assemblers, macro-processors and introduction to compilers; language design issues; structure, names, parameter passing; elements of syntactic and semantic analysis.

91-515 Operating Systems I (3-0)3
Prerequisites: 91-501, 91-502, Pascal (or another Algol family language)
A functional level view of multiprocessing operating systems including processor, memory, peripheral and file systems management in batch, timesharing, real time and distributed systems targeted for various hardware. An OS simulation is a required programming project.

91-516 Operating Systems II (3-0)3
Prerequisites: 91-515 or permission of instructor
The design and implementation of an interactive multiprocessing operating system to run an a bare hardware system (currently a PDP 11-23). Separate teams manage the major subsystems with inclass design reviews to coordinate system integration. A functioning system is a class requirement.

91-517 Systems Programming (3-0)3
Prerequisites: 91-516 or permission of instructor The design and implementation of assemblers, linkers, loaders, editors and higher level translation software. Various systems software will be integrated under the operating system built in 91.516 to facilitate a complete programming environment.

91-518 Performance Evaluation (3-0)3
Prequisites: Probability theory and simulation techniques; consent of instructor.
Creation of mathematical models of various computer systems and networks; application of queueing theory to evaluation, prediction of behavior and comparison of model performance.

91-520 Topics in Operating Systems 3-0)3

91-521 Introduction to Software Engineering (3-0)3
(not available for credit to Computer Science degree students) software development cycle; methods of specification, analysis and planning; introduction to testing and verification; project management.

91-523 Software Engineering I: Structured Analysis & Design (3-3)3
Prerequisites: None; Not open to 91-412 graduates.
A team-based project lab course on the design, implementation and testing of large software projects; life cycle concept, data-flow, data-structure and algebraic specification methods, structured analysis and testing.

91-524 Software Engineering II: Validation and Verification (3-3)3
Prerequisites: 91-523 or 91-412: Software Engineering 1.
Comparative analysis of program development support systems, structured testing and rapid prototyping tools for large software systems. Introduction to formal specifications and proof-of-correctness. Students will contribute to ongoing software tool development projects.

91-526 Project Management **(3-0)3**
Prerequisites: 91-523
Integration of management and software engineering concepts within a project management context; topics include general management techniques, models and metrics, case studies and a significant class project.

91-530 Topics in Software Engineering **(3-0)3**

91-531 Principles of Programming Languages **(3-0)3**
Prerequisites: 91-208 or equivalent, 91-501
This course reviews the organizational aspects and introduces (informally) the underlying semantic principles of programming languages. The latest research in language design is discussed. Project required.

91-532 Organization of Programming Languages **(3-3)3**
(not available for credit to Computer Science degree students)
language organization and design; definition and specification; data types and structures; control structures; procedural, functional and applicative languages; case studies of several current languages.

91-534 Compiler Construction (Introduction) **(3-0)3**
Prerequisites: 91-531 and highly recommended 91-517
This course implements a compiler for a language subset into assembly language. Topics covered are LL parsing, semantic analysis, code generation, optimization, and error recovery. Programming project required.

91-535 Compiler Construction I **(3-0)3**
Prerequisite: 91-534
This course implements a compiler for a complete language. Topics include LR parsing, parser generators, Graham-Gainville code generators, and Kerr optimization. Programming project required.

91-536 Compiler Construction II **(3-0)3**
Prerequisite: 91-535
Continuation of Compiler Construction I.

91-538 Semantics of Programming Languages **(3-0)3**
Prerequisite: 91-531 and 91-502
This course cover various semantic models with emphasis on the Scott-Strachey denotational approach. Project required.

91-540 Topics in Languages and Compilation **(3-0)3**

91-541 Introduction to Artificial Intelligence **(3-0)3**
(not available for credit to Computer Science degree students)
Search strategies and game playing; topics in knowledge representation, reasoning, and/or perception; programming in the LISP language.

91-543 Artificial Intelligence **(3-0)3**
Prerequisites: 91-501, 91-531.
Search and games, knowledge representation paradigms, natural language understanding, planning, perception. Use of the LISP language for one or more programming projects.

91-544 Advanced Artificial Intelligence **(3-0)3**
Prerequisite: 91-543 or equivalent.
Topics from the recent literature. Possible topics will be: natural language understanding, program verification, automatic theorem proving, heuristic search, rule based systems, machine learning, perception.

91-545 Knowledge Based Systems **(3-0)3**
Prerequisites: 91-543, or equivalent.
Rule and non-rule based systems, knowledge acquisition and representation, inference under uncertainty. Well known systems (MYCIN, PROSPECTOR, EL, AM, HEARSAY.) will be examined. Research projects will be assigned.

91-546 Computer Graphics **(3-0)3**
Introduction to the hardware, software and mathematics of 2- and 3- dimensional interactive computer graphics systems, including standards, modelling, transformations, hidden-surface removal, shading and realism.

91-547 Robotics **(3-0)3**
Theory of robotics control, manipulation and vision; current industrial techniques and applications; vision and sensors; factory of the future and productivity.

91-548 Introduction to Computer Aided Design **(3-0)3**
The design specification, implementation and testing of CAD applications, including geometric and database modelling, integrated multiple system concepts (with CAM and CAE), standards and tools.

91-550 Topics in Graphics, Robotics and Artificial Intelligence **(3-0)3**

91-551 Computer Architecture **(3-0)3**
An advanced study of computer system organization. Topics include data path design, control, ALUs, memory organization, distributed processing, theories of parallel computing, advanced architectures, computer communication.

91-553 Microprogramming **(3-0)3**
A study of the use of microprogramming as an implementation technique for computer-based systems. Topics include hardware organization and microinstruction set design, emulation, virtual machines, firmware engineering, microcode compaction.

91-555 Networks **(3-0)3**

91-560 Topics in Architecture

91-561 Introduction to Data Communications **(3-0)3**
(not available for credit to Computer Science degree students) Elements of communication theory; protocols; error detection and correction; system building blocks; management and economic issues.

91-562 Introduction to Networking (3-0)3
(not available for credit to Computer Science degree students)
Fundamentals of distributed computer systems; taxonomy; protocols; switching, routing and flow of control; discussion of various architectures and models; security and recovery.

91-563 Data Communications I (3-0)3
Resources sharing; computer traffic characterizations; multiplexing; network structure; packet switching and other switching techniques; design and optimization; protocols; routing and flow control; simulation and measurement; communications processors.

91-564 Data Communications II
Continuation of 91.563 (3-0)3

91-570 Topics in Data Communications

91-571 Introduction to Data Base Systems (3-0)3
(not available for credit to Computer Science degree students)
Models of database systems; design of systems; issues of security, integrity, concurrency; examination of several existing systems.

91-573 Data Base I (3-0)3
Prerequisite: 91-501, 91-515 and highly recommended 91.517
Study of three database models: hierarchical, network, and relational (including database design). This course also covers integrity, security, concurrency and implementation of a centralized database system.

91-574 Data Base II (3-0)3
Prerequisite: 91-573
Continuation of Data Base I. In depth study of data models, null issue, view update, distributed database and database machines. In the second half of the semester, students design a distributed relational database.

91-580 Topics in Database Systems (3-0)3

91-583 Coding Theory (3-0)3
A mathematical treatment of error-correcting codes for computer science and data communication systems. Topics will include standard array decoding, cyclic codes, and BCH codes.

91-584 Cryptography (3-0)3
Algorithms for secure transmission of information; codes and ciphers; key algorithm; decoding.

91-585 Formal Languages (3-0)3
Languages, grammars and recognizers; Chomsky hierarchy; finite state machines and regular languages; PDAs and context free languages; context sensitive languages and their recognition; Turing Machines; open and unsolvable problems.

91-586 Theory of Computation (3-0)3
Examination of models of computation: Turing Machines, Markov algorithms, etc. Recursive function theory; selected topics.

91-587 Computational Algebra (3-0)3
Construction of software for algebraic problems: linear systems, eigenvalues; singular value decomposition; examination of currently available systems.

91-590 Topics in Computing Theory (3-0)3

91-591 Project (3-0)3

91-592 Directed Study	**(3-0)3**
91-701 Directed Research	**(3-0)3**
91-703 Directed Research	**(9-0)9**
91-704 Directed Research	**(12-0)12**
91-705 Supervised Teaching	

DEPARTMENT OF MATHEMATICS

DEPARTMENT CHAIRPERSON : ALAN W. DOERR, *Professor;* B.S, Marist College; M.A., Hunter College.

GRADUATE COORDINATOR: DONALD L. AMEEN, *Associate Professor;* B.S., Lowell Technological Institute; M.S. Cornell University

Faculty

Susan F. Assmann, *Assistant Professor, Mathematics;* B.A., Dartmouth College; Ph.D., Massachusetts Institute of Technology.
Stephen J. Bodor, Professor, Mathematics; B.S., M.S., Lowell Technological Institute.
John Brode, *Assistant Professor, Mathematics;* B.A., M.A., University of Paris; M.A., Ph.D., Harvard University.
Pasquale Condo, *Associate Professor, Mathematics;* B.S., Purdue University; M.S., Lowell Technological Institute.
Alan W. Doerr, *Professor, Mathematics;* B.A., Marist College; M.A., Hunter College.
Raoul M. Freyre, *Professor, Mathematics;* Sc.D., University of Havana (Cuba).
Enrique Gonzalez-Velasco, *Associate Professor, Mathematics;* B.S., Ph.D., Polytechnic University of Madrid; Sc.M., Ph.D., Brown University.
Gerald Kaiser, *Associate Professor, Mathematics;* B.S., Case Institute of Technology; M.S., Carlton College; M.S., Ph.D., University of Wisconsin; Ph.D., University of Toronto.
Alan Kaplan, *Associate Professor, Mathematics;* B.S., University of Massachusetts; M.S., Ph.D., Syracuse University.
Fernando R. Lasaga, *Assistant Professor, Mathematics;* A.B., Princeton University; Ph.D., Massachusetts Institute of Technology.
Kenneth M. Levasseur, *Assistant Professor, Mathematics;* B.A., St. Anselm's College; M.S., Ph.D., University of Rhode Island.
Yuly Makovoz, *Associate Professor, Mathematics;* M.S., University of Tchernovtsy; Ph.D., Urals University.
Thomas F. McElligott, *Professor, Mathematics;* A.B., Mt. St. Mary's College; Ed.M., Boston University.
Thomas McPhee, *Lecturer, Mathematics;* B.A., University of Massachusetts, Amherst, M.S.C.S., Boston University.
Guntram B. Mueller, *Associate Professor, Mathematics;* B.S., Loyola College (Montreal); M.S., Ph.D., Notre Dame University.
Stephen A. Pennell, *Assistant Professor, Mathematics;* B.S., Rensselaer Polytechnic Institute; Sc.M., Ph.D., Brown University.
Shelley L. Rasmussen, *Associate Professor, Mathematics;* B.S., M.A., Central Michigan University; M.A., Ph.D., University of Michigan.

Mary Beth Ruskai, *Associate Professor, Mathematics;* B.S., Notre Dame College; M.S., Ph.D., University of Wisconsin.
Neal Sorenson, *Lecturer, Mathematics;* B.A., M.A., Brigham Young University, Ph.D. University of Utah.
Stanley L. Spiegel, *Associate Professor, Mathematics;* B.S., New York University; A.M., Ph.D., Harvard University.
Marvin E. Stick, *Associate Professor, Mathematics;* B.S., Boston College; M.A., Boston University; Ph.D., Boston College.
Virginia S. Taylor, *Professor, Mathematics;* B.S., Syracuse University; M.A., Western Michigan University; Ph.D., Boston College.
Paul Tress, *Lecturer,* B.A., Cornell University, M.A., M.S.E.E., Ph.D., Michigan State University.
I. Jacob Weinberg, *Professor, Mathematics;* B.S., Yeshiva University; S.M., Ph.D., Massachusetts Institute of Technology.
Joyce W. Williams, *Associate Professor, Mathematics;* B.A., University of Minnesota; M.S., Ph.D., University of Illinois.
Edwin Wolf, Assistant *Professor, Mathematics;* B.A., Amherst College; M.A., Ph.D., Brown University.

MASTER OF SCIENCE DEGREE PROGRAM

There are four options available in this program:

A. Applied Mathematics
B. Computers
C. Mathematics for Teachers
D. Statistics and Operations Research

The requirements for admission to each of the options are described in the sections below. All four options require a four-year undergraduate degree from an accredited college or university with a satisfactory grade point average, and the aptitude part of the Graduate Record Examination. Applicants lacking some prerequisites may be enrolled as provisional students. All application materials must be received by May 20.

All programs consist of thirty credit hours approved by the Graduate Curriculum Committee. Graduate course offerings from other departments and a maximum of six credit hours at the 400 level may be considered for inclusion in the program of study.

Courses will be offered on a regular basis in the late afternoon and early evening so that all programs may be completed on a part-time basis.

A. *Applied Mathematics*

This option is designed to provide the mathematical skills necessary to solve a variety of industrial, commercial, and engineering problems.

Prerequisites are mathematics through multivariable calculus, ordinary differential equations, linear algebra, and mathematical analysis.

Students in the program will take courses which introduce them to a variety of mathematical techniques and their application to real-world problems. Either 3 or 6 credits of course work can be replaced with a master's thesis. A 6 credit thesis will be presented to and approved by a subcommittee of the Graduate Faculty. A specific plan of study will be designed in cooperation with the student's faculty advisor. Upon completion of the program, the student will have gained basic knowledge of both discrete and continuous applied mathematics.

B. *Computers*

This option is designed for students with little formal education in computer science or mathematics.

Prerequisites are knowledge of PASCAL and courses in Computer Organization, Discrete Structures, and Data Structures. (The corresponding courses at University of Lowell are 92-265 Pascal, 92-367 Assembler, 92-321 Discrete Structures, and 92-360 Data Structures.)

The Core Program consists of the following four required courses:

92-521 Algebraic Structures I
92-560 Data Structures and Algorithms I
92-575 Data Structures and Algorithms II
92-568 Operating Systems

The remainder of the program is selected with the approval of the Graduate Curriculum Committee from the graduate offerings in Computer Science, Mathematics and Statistics, and graduate offerings from other departments. One of these six elective courses must be a 3-credit mathematically oriented graduate course such as Graph Theory, Introduction to Discrete Mathematics, Numerical Algebra, or Linear Optimization. Substitutions can be made with approval of the graduate coordinator.

C. *Mathematics for Teachers*

This option is designed to broaden and deepen the background of primary and secondary school teachers of mathematics.

Prerequisites are single variable and multivariable calculus.

The program consists of two sequential courses in Analysis (either 92-501 and 92-502 or 92-511 and 92-512), one course in algebra, one course in geometry, and one course in applied mathematics, statistics, or computer science. The remaining five courses may be chosen from any of these areas.

From time to time the Mathematics Department offers brief one or two week seminars at the graduate level. Ordinarily these courses will not be credited toward the M.S. degree. In those cases where credit might be given, written approval prior to registration must be obtained from the graduate coordinator.

In order to meet the shortage of high school teachers of mathematics, the department offers a program designed to assist teachers in obtaining certification. A number of these courses are applicable to the Mathematics for Teachers option. This program is described in a separate brochure.

D. *Statistics and Operations Research*

This option is a professionally oriented program which provides the necessary mathematical skills to solve many of the data analysis problems of government, industry, science, engineering, and management.

Prerequisites are mathematics through multivariable calculus, ordinary differential equations, linear algebra, and at least an introductory knowledge of probability and mathematical statistics.

Of the thirty credits required for the degree, 24 are in course work in statistics, computer science, operations research, and other approved areas. The remaining six credits are in directed research. The program is a

flexible one; each student will select courses that fit his or her special interests and needs, with the advice and approval of the faculty advisor.

Five Year B.S./M.S. Program

The department has a five year B.S./M.S. program for outstanding undergraduates. See the undergraduate catalog for details.

Course of Study

90-553 Systems Simulation **(3-0)3**

Prerequisite: Knowledge of FORTRAN and Assembly Language

Procedures in model construction and computerized simulation, modeling tools and techniques, model conceptualization and implementation, selected applications of simulation.

90-554 Minicomputer Principles and Applications **(3-0)3**

Prerequisite: Assembler Language

Current minicomputer practices covering both hardware and software including basic minicomputer instruction sets, operating systems, assembler and I/O programming, utilities, interrupts, and interfaces. Applications to Science and Business.

90-555/556 System Design and Development I,II **(3-0)3 (3-0)3**

Prerequisite: Assembler Language and PASCAL

Design and development of computer-oriented data processing systems including: the approach requirements of the system, developing the solution, data controls, system controls, system evaluation and reporting to management.

90-577 Programming Languages **(3-0)3**

An introduction to the formal concepts of programming languages including specifications of syntax and semantics. Examination of programming languages with emphasis on practical applications.

91-511 Operating Systems Introduction **(3-0)3**

Prequisite: Assembler Language and Data Structures

Models of operating systems; concurrency and parallelism; synchronization; multiprogramming; memory and resource management; scheduling; protection; file-structure.

91-512 Systems Programming Introduction **(3-0)3**

Prerequisite: Assembler Language and Data Structures

Assemblers, macro-processors and introduction to compilers; language design issues; structure, names, parameter passing; elements of syntactic and semantic analysis.

91-521 Introduction to Software Engineering **(3-0)3**

Prerequisite: Data Structures

Software development cycle; methods of specification, analysis and planning; introduction to testing and verification; project management.

91-532 Organization of Programming Languages **(3-3)3**

Prequisite: Discrete Structures and Pascal

Language organization and design; definition and specification; data types and structures; control structures; procedural, functional and applicative languages; case studies of several current languages.

91-533 Introduction to Compilers (3-0)3

Prequisite: PASCAL and Data Structures

An introduction to languages and compilation techniques; symbol tables; syntax analysis and parsing; semantics; code generation and optimization.

91-541 Introduction to Artificial Intelligence (3-0)3

Prequisite: Assembler Language

Search strategies and game playing; topics in knowledge representation, reasoning, and/or perception; programming in the LISP language.

91-561 Introduction to Data Communications (3-0)3

Prerequisite: Knowledge of Data Processing Systems

Elements of communication theory; models; protocols; error detection and correction; system building blocks; management and economic issues.

91-562 Introduction to Networking (3-0)3

Prerequisite: Data Communications

Fundamentals of distributed computer systems; taxonomy; protocols; switching, routing and flow of control; discussion of various architectures and models; security and recovery.

91-571 Introduction to Data Base Systems (3-0)3

Prerequisite: Permission of Instructor

Models of database systems; design of systems; issues of security, integrity concurrency; examination of several existing systems.

92-501/502 Real Analysis I,II (3-0)3, (3-0)3

Real and complex number systems. Set Theory. Bolzano-Weierstrass and Heine-Borel theorems. Sequences and series. Continuity. Differentiation. Riemann integration. Sequences and series of functions. Functions of several variables. Measure and integration.

92-505 Introduction to Discrete Mathematics (3-0)3

Prerequisite: Linear Algebra or Discrete Structures.

Basic counting rules, permutations and combinations, recurrence relations. Asymptotic algorithms analysis, NP-completeness, heuristic algorithms. Linear, integer, and dynamic programming. Coding Theory. Applications.

92-511/512 Complex Variables I,II (3-0)3, (3-0)3

Complex numbers, elementary functions and their geometric representation. Differentiation and integration. Power series. Singularities. Entire and meromorphic functions. Periodic functions.

92-513 Number Theory (3-0)3

Study of primes, congruences, number-theoretic functions, Dirichlet series, quadratic forms and quadratic number fields. Additional topics as time permits.

92-514 Calculus From an Advanced Viewpoint (3-0)3

This course is designed to provide students in the teacher option with the background necessary to teach Advanced Placement Mathematics.

92-515 Complex Analysis (3-0)3

Prerequisite: Mathematical Analysis.

Differentiation and integration of complex analytic functions. Cauchy's integral theorem and formula. Singularities and Laurent series. Theory of residues and applications. Harmonic functions. Conformal mapping.

92-521/522 Algebraic Structures I,II (3-0)3, (3-0)3

Properties of rings, groups, fields, polynomials over fields, extension rings and fields, vector spaces, codes, and additional applications. Students in the computer option must take 92.321 prior to 92.521.

92-523/524 Linear Algebra I,II **(3-0)3, (3-0)3**
Sets and maps. Vector spaces and linear maps. The matrix of a linear map . Scalar product and orthogonality. Bilinear maps. Triangulation. The spectral theorem.

92-527/528 Geometry I,II **(3-0)3, (3-0)3**
Transformation in Eucliean Geometry. Hyperbolic, and inversive geometries. Caroms, golden ratio, convexity, theorems of Ceva, Menelaus, and Morley. Incidence geometry, collinations, synthetic and analytic projective geometry. Cross ratio, polarities, finite geometries. Hyperbolic geometry.

92-529 Differential Geometry **(3-0)3**
Differential Geometry involving curves and surfaces in 3-space. Curvature, torsion, Frenet equations, intrinsic equations, involutes and evolutes.

92-530/531 Applied Mathematics I,II **(3-0)3 (3-0)3**
Matrices, vector analysis, divergence, Green's and Stokes' theorem, series solution of differential equations, boundary value problem. Fourier series and integrals. Partial differential equations, separation of variables.

92-537/538 Vector and Tensor Analysis I,II **(3-0)3, (3-0)3**
The geometry of curves and surfaces, Serre-Frenet formulas, intrinsic equations of a curve, first and second fundamental forms of a surface, divergence, curl, and gradient. Tensor algebra, covariant and contravariant differentiation and parallel displacement. Applications to differential geometry and selected topics.

92-541/542 Fourier Analysis and Boundary Value Problems I,II. **(3-0)3, (3-0)3**
Prerequisite: Mathematical Analysis.
Fourier series and integrals. Orthogonal systems and Sturm-Liouville problems. Applications to boundary value problems in rectangular, cylindrical, and spherical coordinates. Distributions and their applications.

92-543 Ordinary Differential Equations **(3-0)3**
Prerequisite: Mathematical Analysis.
Existence, uniqueness, and smoothness of solutions. The Poincare'-Bendixson theory. The neighborhoods of critical points and closed orbits. Liapunov stability. Linear and perturbed linear systems.

92-545/546 Partial Differential Equations I,II **(3-0)3, (3-0)3**
Introduction to partial differential equations in the plane and space, with engineering applications. Solution of initial-and boundary-value problems. Complex variables and transform theory.

92-547 Integral Equations **(3-0)3**
Exact, iterative, and numerical techniques for the solution of linear Volterra and Fredholm integral equations, theorems for general operators. Symmetric kernels, orthogonal system of functions, and the Hilbert-Schmidt theorem. Applications.

92-548 Mathematics of Signal Processing I **(3-0)3**
Prerequisite: Mathematical Analysis.
Representation of signals: Fourier analysis, fast Fourier transforms, orthogonal expansions. Transformation of signals: linear filters, modulation. Band-limited signals. Sampling. Uncertainty principle. Windows and extrapolation.

92-551 Calculus of Variations **(3-0)3**
Prerequisite: Mathematical Analysis.
The first variational problem: necessary conditions. Euler's equation. Generalization to dependent and independent variables. Constraints and Lagrange multipliers. Application to dynamics and elasticity. Direct methods.

92-560 Data Structures and Algorithms I (3-0)3

Prerequisite: Discrete Structures and Pascal.

Implementations of lists, stacks, queues, ordered and binary trees, and priority queues. Tree traversals. Open and closed hashing. Directed graphs: shortest paths and acyclicity. Algorithm analysis techniques.

92-563 Numerical Analysis (3-0)3

Prerequisite: Mathematical Analysis.

Non-linear equations in one and several variables. Numerical differentiation and integration. Numerical methods for ordinary differential equations and for the Laplace, heat, and wave equations.

92-564 Numerical Algebra (3-0)3

Solution of linear systems. Eigenvalue, eigenvector problem. Fast Fourier Transform. Introduction to finite elements. Least squares. Splines, Chebyshev approximation.

92-565 Formal Languages (3-0)3

Prerequisite: Pascal.

Principles of finite automata. Properties of languages accepted by finite automata. Context-free grammars and push-down automata. Turing machines and computability.

92-566 Theory of Computation (3-0)3

Prerequisite: PASCAL

Computability, undecidability, complexity. Turing machines and the halting problem. Elementary recursion theory. The Church-Turing thesis. Measures of complexity, the speed-up theorem. Proving theorems about programs.

92-571 Linear Optimization (3-0)3

Simplex and revised simplex methods, duality, sensitivity analysis, the transportation problem and other applications, degeneracy procedures, computational techniques. Introduction to integer programming.

92-572 Non-Linear Optimization (3-0)3

Unconstrained optimization, Lagrange multipliers, Kuhn-Tucker theory, quadratic programming, convex programming, numerical methods.

92-575 Data Structures and Algorithms II (3-0)3

Prerequisite: Data Structures and Algorithms I.

Divide and conquer, radix and comparsion sorts, order statistics, optimal binary trees, union-find, balanced trees, graph connectivity, path finding, matrix multiplication, fast Fourier transform, pattern matching, NP-completeness.

92-580 Combinatorics (3-0)3

Prerequisite: Introduction to Discrete Mathematics.

Generating functions, recurrence relations, inclusion-exclusion, Polya theory. Experimental designs (block design). Partially ordered sets. Applications.

92-581 Graph Theory (3-0)3

Prerequisite: Linear Algebra or Discrete Structures, Terminology, theorems, algorithms, and applications of graph theory. Trees, circuits, and connectivity. Hamiltonian and Eulerian graphs. Shortest routes, matching, network flows. Covering, coloring, Ramsey theory.

92-582 Time Series Analysis (3-0)3

Prerequisite: Permission of the instructor.

Building models for discrete time series and dynamic systems, and their use in forecasting and control. Stationary and non-stationary time series models. Model identification, estimation and checking, with applications. Box-Jenkins (ARMA) and other techniques.

92-584 Stochastic Processes **(3-0)3**

Prerequisite: Probability or Mathematical Statistics I.

Markov chains and processes, random walks, stationary, independent increments, and Poisson processes. Ergodicity. Examples (e.g. diffusion, queuing theory, etc.).

92-585 Queueing Theory **(3-0)3**

Prerequisite: Statistics and Probability

Single-server queueing systems, queue length, and waiting time. Multi-server queueing systems. Modeling of telephone systems, interactive computer systems.

92-586 Coding Theory **(3-0)3**

Prerequisite: Discrete Structures

Error correcting and decoding with selected topics from information theory and cryptography, with emphasis on practical applications in data processing, transmission and security. Linear block codes, cyclic codes, convolution codes and arithmetic codes. Applications from communications and computer science.

92-587/588 Mathematical Statistics I, II **(3-0)3, (3-0)3**

Random variables, densities, joint and conditional distributions, expectations, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

92-591 Statistical Modeling and Data Analysis **(3-0)3**

Prerequisite: Probability, Biostatistics, or Statistics for Engineering and Science.

Model building via linear regression models. Method of least squares, theory and practice. Checking for adequacy of a model, examination of residuals, checking outliers. Practical hands-on experience in linear model building on real data sets.

92-592 Multivariate Statistical Modeling **(3-0)3**

Nonlinear model building via the method of least squares. Discriminant analysis, factor analysis, principal components, profile analysis, canonical correlation, cluster analysis. Hands-on experience of multivariate statistical analysis of real data sets.

92-593 Design of Experiments **(3-0)3**

How to design, carry out, and analyze an experiment to obtain valid results. Randomized block designs, randomization, blocking, matching, analysis of variance and covariance, control of extraneous variables.

92-594 Control Theory **(3-0)3**

Prerequisite: Mathematical Analysis

Analytical and numerical methods for optimization of deterministic and stochastic dynamic systems.

92-595 Information Theory **(3-0)3**

Prerequisite: Mathematical Analysis

Shannon theory including information measure and transmission rates and capacities. Elements of coding theory.

92-596 Finite Elements **(3-0)3**

Prerequisite: Mathematical Analysis

Mathematical formulations and techniques including an introduction to variational methods. Examples from solid mechanics, heat transfer, and fluid mechanics.

92-597 Probabilty and Mathematical Statistics **(3-0)3**

Prerequisite: Mathematical Analysis

Elementary introduction: combinatorics, geometric probabilities, algebra of probabilities, random variables, classic distributions. Measure-theoretic axiomatics. Analytical methods. Limit theorems. Statistical methods: sampling, estimation, regression and correlation.

92-598 Functional Analysis (3-0)3

Prerequisite: Mathematical Analysis

Geometry of general metric spaces with an emphasis on Banach and Hilbert spaces. Spectral theory of operators. Typical applications (e.g. to differential and integral equations, numerical analysis, and quantum mechanics).

92-599 Approximation Theory (3-0)3

Prerequisite: Mathematical Analysis

Uniform approximation by polynomials. The Weierstrass and Jackson theorems. Characterization of best approximation. Least squares approximation. Approximation by splines and rational functions.

92-651/652 Directed Studies I,II (3-0)3, (3-0)3

Prerequisite: Permission of instructor

This course is intended to satisfy individual student needs. Topics include various fields of mathematics.

92-653/659 Selected Topics I,II (3-0)3

Prerequisite: Permission of instructor

Advanced topics in various fields of mathematics and related fields. Since topical coverage varies from term to term, a student may be allowed to receive credit more than once for this course.

92-701/702 Graduate Research in Mathematics (3-0)3,(3-0)3

Directed research leading to a master's thesis.

DEPARTMENT OF PHYSICS AND APPLIED PHYSICS

DEPARTMENT CHAIRPERSON: ZOLTAN FRIED, *Professor;* B.S., Brooklyn College; Ph.D., Brandeis University.

GRADUATE COORDINATOR: LLOYD KANNENBERG, *Professor;* S.B., Massachusetts Institute of Technology; M.S., University of Florida; Ph.D., Northeastern University.

Faculty

Edward L. Alexander, *Professor;* B.S., M.S., University of Maine; Ph.D., Vanderbilt University.
Albert Altman, *Professor;* B.S., Brooklyn College; M.S., Ph.D., University of Maryland.
Adolph Baker, *Professor;* B.A., City College of New York; B.M.E., Polytechnic Institute of Brooklyn; M.S., in Ed., City College of New York; M.S., New York University; Ph.D., Brandeis University.
Leon E. Beghian, *Professor and Associate Vice President for Research;* B.A., D.Phil., University of Oxford.
Klaus Bibl, *Research Professor;* Ph.D., University of Freiburg, Germany.
George E. Chabot, *Adjunct Assistant Professor;* A.B., Harvard University; M.S., Harvard School of Public Health, (C.H.P.).
Gus Couchell, *Professor;* B.S., M.S., North Carolina State University; Ph.D., Columbia University.
James J. Egan, *Professor;* B.A., Thomas More College; M.S., Ph.D., University of Kentucky.
Padmanabh Harihar, *Associate Professor;* B.Sc., R. Ruia College; M.Sc., Wilson College, India, Ph.D., Columbia University.
Jesse Y. Harris, *Professor;* B.S., M.S., Ph.D., Rutgers-The State University.

Aram S. Karakashian, *Professor;* B.S., M.S., Temple University; Ph.D., University of Maryland.
Gunter H.R. Kegel, *Professor;* B.Fis., Universidade de Brasil; Ph.D., Massachusetts Institute of Technology.
Dennis Leiner, *Assistant Professor;* B.S., M.S., University of Rochester; Ph.D., University of Connecticut.
Anthony Liuzzi, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., New York University, (C.H.P.).
Suresh C. Mathur, *Professor and Director of the Computer Center;* B.Sc., University of Lucknow; Ph.D., University of Texas.
Roger D. McLeod, *Associate Professor;* B.A., Bowdoin College, M.S., Lowell Technological Institute.
Walter K. Mellen, *Associate Professor;* S.B., Massachusetts Institute of Technology; M.S., Lowell Technological Institute.
Arthur Mittler, *Professor;* B.A., Drew University; M.S., Ph.D., University of Kentucky.
David J. Pullen, *Professor;* B.Sc., University of London; D.Phil., University of Oxford.
Walter A. Schier, *Professor;* B.S., Saint Procopius College; Ph.D., University of Notre Dame.
Kunnat Sebastian, *Professor;* B.S., M.S., Kerala University; Ph.D., University of Maryland.
Eric Sheldon, *Professor;* B.Sc., (Gen) and B.Sc., (Special Honors), D.Sc., D. Phil., University of London.
Kenneth W. Scrable, *Professor;* B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers-The State University, (C.H.P.).
Richard W. Stimets, *Associate Professor;* B.S., Ph.D., Massachusetts Institute of Technology.
Ye Yung Teng, *Associate Professor;* B.S., National Taiwan University, China; M.S., Ph.D., University of Maryland.
Jerry Waldman, *Professor;* B.A., M.A., Columbia University; Ph.D., Massachusetts Institute of Technology.
Martin Wilner, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Yale University; Ph.D., Massachusetts Institute of Technology.
Chuen Wong, *Associate Professor;* Diploma of Science, Chung Chi College, Hong Kong; Ph.D., Case Western Reserve University.

PHYSICS AND APPLIED PHYSICS

Research Programs

Members of the Department are engaged in research programs in the following areas in which opportunities for advanced degree thesis research are offered: Theoretical and Experimental Nuclear Physics, Theoretical and Experimental Solid State Physics, Laser Physics, Optics, Theory of Elementary Particles, Quantum Field Theory, Atomic Physics, Relativity, Atmospheric Physics, Biophysics, Nuclear and Solar Energy, Applied Mechanics Computational Physics, Radiological Sciences and Medical Physics.

Research facilities at the Radiation Laboratory include a megacurie ^{60}Co source, a 5.5 MeV van de Graaf accelerator, a one-megawatt nuclear reactor, two Hewlett-Packard System 1000 computers and other instruments. The Solid State and Optics Laboratory contains a diffusion furnace, two thin film evaporators, Fourier transform and ATR spectrometers, a scanning monochromator, dye, infrared, and far infrared lasers, and a PDP 11/23 computer. The University has a Cyber 170-825 computer available for both batch and time-shared usage.

Entering Graduate Students

Every entering graduate student is assigned a departmental adviser who will advise on programs of study and other academic requirements, serve as

registration officer, help the student to become acquainted with research opportunities in the Department, and assist in selecting a thesis supervisor.

Entering graduate students are expected to have a sound background in intermediate level mechanics, electricity and magnetism, thermodynamics and statistical mechanics, and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove the deficiency.

Master of Science Degree Program

The Master's program in Physics provides an opportunity for advanced study and research in most of the areas mentioned above. The Master's Program in Radiological Sciences is described elsewhere in the catalog.

Graduate Credits and Course Requirements

At least 30 graduate credit hours are required, of which at least 6 and at most 12 are to be thesis research 96-701, 702, or, if a project is approved by the Department in place of Master's thesis, a maximum of 3 credits of graduate research will be allowed. At most, 3 credits of departmental colloquium and seminar courses may be applied to the 30 credit requirement.

A candidate for the M.S. degree electing to specialize in a particular area of applied physics will be required to complete a sequence of courses no later than the end of the third semester of study. These courses, are as follows:

95-505/506	Mathematical Methods of Physics	(4-0)(4-0)8
95-511	Classical Mechanics	(3-0)3
95-557	Electromagnetic Theory I	(4-0)4

Electives may be chosen from the list of courses acceptable for graduate credit in Physics, but explicit departmental approval is required for graduate credit in 95-461, Topics in Nuclear Physics, and 95-472, Solid State Physics. Some graduate courses offered by other departments may also be acceptable for graduate credit in Physics, but only with the approval of the Physics department.

Colloquia

All full-time M.S. candidates are required to attend Department colloquia, 95-601/602, each semester.

Seminars

All full-time M.S. candidates are required to take at least one Physics Seminar, in addition to the Colloquium each semester.

Language

There are no foreign language requirements for the M.S. degree in Physics.

Thesis or Project

The thesis or project is to be based on research performed under the supervision of a member or associate of the Graduate Faculty. If a student

wishes to do a thesis under the supervision of a faculty member in another Department or at the University of Lowell Research Foundation, consent of the Physics Department must be obtained. The student must submit to the Department, for its approval, two copies of a typewritten proposal briefly describing the project of the problem to be solved for the thesis. This proposal must bear the written approval of the research supervisor. A student may not register for 96-701/702, Graduate Research, until the proposal has been approved, although registration for 96-711/712, Special Problems may begin sooner. After completing the work, the student must submit three copies of a typewritten dissertation based on it to the Department. The student must then pass an oral examination, administered by the Dissertation Committee of the Department. The examination will be based on, but not necessarily restricted to, the subject of the dissertation. A student who submits a project in place of a thesis will be examined also on the subjects all physics M.S. candidates are expected to know. (These are expected to be the subjects in the recommended M.S. course sequence.)

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

The Doctor of Philosophy programs in Physics and Applied Physics are designed to develop advanced competence in Physics. The Physics concentration prepares the student to carry out original and independent research in physics, while the Applied Physics Concentration provides training for professional work in several areas of applied physics and allied engineering disciplines.

Graduate Credits
At least 60 graduate credit hours are required, of which at least 15 and at most 24 are to be thesis research, 96-701/702. Credits in 96-701/702 which were accepted in partial fulfillment of the M.S. degree requirements may not be accepted for the Ph.D. requirement. At most 3 credits of general departmental colloquium and seminar courses may be applied to the 60 credit requirement.

Colloquia
All full-time Ph.D. candidates are required to attend Department colloquia, 96-601/602, each semester.

Seminars
All full-time Ph.D. candidates are required to take at least one Physics Seminar, in addition to the Colloquium, each semester.

Language
All candidates are required to demonstrate at least journal level (Level 2) proficiency in French, German or Russian.

Other Skills
All candidates are required either (a) to demonstrate at least journal level

proficiency in a foreign language from among French, German or Russian in addition to that used for the language requirement, or (b) to demonstrate proficiency in computer programming. This may be validated by achieving a grade of at least B in courses such as Fortran Programming or Introduction to Pascal, or by demonstrating equivalent competence to the Physics Department.

Comprehensive Examination
All candidates must pass the Physics Comprehensive Examination. Students in the Physics concentration are expected to take this examination in their first year; those in the Applied Physics concentration, in their second year. The written part of the examination covers Classical Mechanics, Electricity and Magnetism, and Quantum Mechanics and Modern Physics at the undergraduate level. If the student passes the written part, on oral examination is given, normally within one year. It will be based on Advanced Projects (95-751/752) or their equivalents, and the graduate level courses taken in the first year.

Thesis
The thesis is to be based on original research performed under the supervision of a member or associate of the Graduate Faculty holding an earned Ph.D. degree. If a student wishes to do a thesis under the supervision of a faculty member in another department, or at the University of Lowell Research Foundation, consent of the Physics Department must be obtained. The student must submit to the Department, for its approval, two copies of a typewritten proposal briefly describing the problem to be solved for the thesis. The proposal must bear the written approval of the research supervisor. A student may not register for 96-701, 702, Graduate Research, until the Comprehensive Examination has been passed and the thesis proposal has been approved, although registration for 96-711, 712, Special Problems, may begin sooner. After completing the work, the student must submit four copies of a typewritten dissertation based on it to the Department. The student must then pass an oral examination, administered by the Dissertation Committee of the Department, based on but not necessarily limited to the thesis work.

THE PHYSICS CONCENTRATION

The following courses are required:

95-505/506	Mathematics Methods of Physics	(4-0)(4-0)8
95-511	Classical Mechanics	(3-0)3
95-515/516	Quantum Mechanics	(3-0)(3-0)6
95-557/558	Electromagnetic Theory	(4-0)(4-0)8
95-517	Advanced Quantum Mechanics I	(3-0)3
	or	
95-518	Advanced Quantum Mechanics II	(3-0)3
95-751/752	Advanced Projects in Physics	(3-0)(3-0)6

This requirement will be waived for students already holding a Master's degree in Physics.

Electives may be chosen from the list of courses acceptable for graduate credit in Physics, but explicit Department approval is required for graduate credit in 95-461, Topics in Nuclear Physics, and 95-472, Solid State Physics. Some graduate courses offered by other departments may also be acceptable for graduate credit in physics, but only with the approval of the Physics department.

THE APPLIED PHYSICS CONCENTRATION

Students in the Applied Physics Concentration may select a program of study and research in one of the following five areas:

1. Physics/Energy Engineering
   (a) Nuclear Energy Option
   (b) Solar Energy Option
2. Physics/Applied Mechanics
3. Physics/Computation
4. Physics/Radiological Sciences
5. Physics/Solid State Mechanics
6. Medical Physics

Areas 1 and 2 are interdisciplinary programs with the Department of Mechanical and Energy Engineering. Area 3 involves the formulation, codification, simulation and solution of complex problems in physical systems using modern computers. Area 4 is an extension of the M.S. program in Radiological Sciences and Protection. Area 5 involves the development of novel solid state electro-optic, acousto-optic,and photovoltaic devices. Area 6 deals with a variety of research projects related to applications of physics to medicine.

General Required Courses

Every student in the Applied Physics Ph.D. Concentration must satisfy the following course requirements:

(a) Demonstration of proficiency in the following courses:

95-513 (A)	Classical Mechanics	(3-0)3
95-553/4(A)	Electromagnetism	(3-0)(3-0)6
95-535/6(A)	Intro Quantum Mechanics	(3-0)(3-0)6
95-505/6	Mathematical Methods of Physics	(4-0)(4-0)8

(b) Six or eight credits from among the following courses, or their equivalents, as appropriate for each particular area of concentration:

95-511 (A)	Classical Mechanics	(3-0)3
95-522 (A)	Statistical Mechanics and Thermodynamics	(3-0)3
95-515/6	Quantum Mechanics	(3-0)(3-0)6
95-517/8	Advanced Quantum Mechanics	(3-0)(3-0)6
95-557/8	Electromagnetic Theory	(4-0)(4-0)8

(c) 95-751/2 Advanced Projects in Physics (3-0)(3-0)6
or their equivalents in the department appropriate to the student's chosen field of concentration. This will be waived for students already having a Master's degree.

Physics/Energy Engineering
In addition to the general requirements, students in this area must take at least seven additional courses from among the Physics, Energy Engineering, and Mechanical Engineering offerings at the graduate level. These seven courses should include required courses appropriate to each Option.

Applied Mechanics
In addition to the general requirements, students in this area must take at least two graduate courses from the Mechanical Engineering Department, the courses to be determined by the student's academic and research advisors.

Computational Physics
In addition to the general requirements, students in this area must take the following courses:

92-563/4	Advanced Numerical Analysis	(3-0)(3-0)6
92-557	Programming Languages	(3-0)3

Radiological Sciences
See Radiological Sciences and Protection section following in this catalog.

Solid State-Optics
In addition to the general requirements, students in this area must take the following courses:

95-472	Solid State Physics	(3-0)3
95-605/6	Seminar in Solid State-Optics	(1-0)(1-0)2
80-539	Electro-Optics	(2-3)4
80-547	Lasers	(2-3)4
80-551	Fiber Optics	

and may choose electives from among courses offered by other Departments, subject to the approval of the Physics Department.

Medical Physics
In addition to the general requirements, students in this area must take six credits of topical seminars dealing with various aspects of medical physics. Because of limited facilities, the acceptance process for students to this area is highly selective.

Courses of Study
The courses whose numbers are followed by the letter 'A' are intended only for graduate students in the Applied Physics Concentration.

95-513(A) Mechanics **(4-0)4**
Prerequisite: 92-208 or equivalent
Kinematics of a particle, analysis or Newton's laws, mechanics of a particle, conservative and non-conservative forces, the linear oscillator, central force motion, kinematics and elastic collisions for two particles, many-particle systems, generalized coordinates, Lagrange's equations, Hamiltonian function.

95-535(A) Introductory Mechanics I **(3-0)3**

Prerequisite: 95-210 or equivalent

De Broglie waves, the Schroedinger equation, wave functions, wave packets, Heisenberg uncertainty principle, expection values, particle in a box, the simple harmonic oscillator, free particles, step barrier, barrier penetration, square well potential.

95-536(A) Introductory Quantum Mechanics II **(3-0)3**

Prerequisite: 95-335

The three dimensional Schroedinger equation, the deuteron nucleus, angular momentum, spin, the hydrogen atom, spin-orbit interaction, Zeeman effect, Pauli exclusion principle, atomic structure, spectroscopic nomenclature, and molecular structure.

95-553(A) Electromagnetism I **(3-0)3**

Prerequisite: 92-208, 95-210 or equivalent

The theory of electromagnetic fields using vector analysis and Maxwell's equations; static electric and magnetic fields in conductors and dielectrics, scalar and vector potentials, solutions to Laplace's equation, image charge problems, and energy density problems.

95-554(A) Electromagnetism II **(3-0)3**

Prerequisite: 95-353

Time-varying electromagnetic fields, ferromagnetic materials, propagation of plane waves in conductors and dielectrics, Snell's law, Fresnel equations, polarization, and radiation from accelerated charges and antennas.

95-505/506 Mathematical Methods of Physics **(4-0)(4-0)8**

Prerequisite: Permission of Instructor

Vector and Cartesian tensor analysis; matrices and determinants; partial differential equations, boundary value problems and special functions. Numerical analysis and applications; theory of analytic functions; Green's functions.

95-507 High-Energy Physics **(3-0)3**

Prerequisite: 95-516

A survey designed for the non-specialist. Elements of relativistic scattering theory, the quantum numbers and conservation laws of high-energy physics, strong and weak interactions, dispersion relations. Regge poles and unitary symmetry.

95-511 Classical Mechanics **(3-0)6**

Prerequisite: Permission of Instructor

Lagrangian formulation of mechanics (including Lagrange multipliers), the Kepler problem and Rutherford scattering; rotating coordinate systems and rigid body motion; small oscillations and stability problems; Hamiltonian formulation.

95-515/516 Quantum mechanics **(3-0)(3-0)6**

Prerequisite: 95-511 concurrently

Wave packets and free particle motion, the wave function and the Schrodinger equation, the linear harmonic oscillator, the WKB approximation, central forces and angular momentum, spin, and time-dependent and time-independent perturbation theory, scattering theory.

95-517/518 Advanced Quantum Mechanics **(3-0)(3-0)6**

Prerequisite: 95-516

Formal theory of scattering; Klein-Gordon and Dirac equations and simple applications; quantum theory of radiation. Symmetry principles and elements of group theory; introduction to many-body theory; Hartree-Fock self-consistent calculations and their applications to atomic, solid state, and nuclear physics.

95-521/522 Statistical Thermodynamics **(4-0)(3-0)7**

Prerequisited: Permission of Instructor

Review of classical thermodynamics; probability and statistical methods for macroscopic systems;

atomic basis of thermodynamics and microscopic definitions of thereodynamic quantities; entropy and related quantities; TdS equations, Maxwell relations, equations of state; canonical and grad canonical ensembles; phase transitions, quantum statistics. The classical statistical mechanics of Gibbs and Darwin-Fowler, the quantum statistical mechanics of Fermi-Dirac and Bose-Einstein; applications of theories.

95-557/558 Electromagnetic Theory **(4-0)(4-0)8**
Prerequisite: 95-506
Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equasions, special relativity, waveguides, Mie scattering, radiation accelerated charges, diffraction, plasma physics.

95-560 Applied Quantum Mechanics **(3-0)3**
Prerequisite: 95-516
Applications of Dirac equation for the electron. Symmetry principles, elements of group theory. Introductory many-body theory, Hartree-Fock calculations, applications to many-electron systems and nuclei. Application of quantum theory of radiation to emission, absorption, width and intensities of spectral lines, selection rules, nuclear multipole moments, and transition probabilities.

95-561/562 Nuclear Physics **(3-0)(3-0)6**
Prerequisite: Permission of Instructor
Stationary states of nuclei, nuclear charge radius, mass, moments, parity, and statistics; theory of alpha, beta, and gamma decay; fission reactions induced by charged particles, gamma rays, and neutrons; nuclear forces and nuclear models; fast neutron physics.

95-573/574 Advanced Theory of Solids **(3-0)3**
Prerequisite: 95-516 and Permission of Instructor
Lattice vibrations and their interactions with X-rays, neutrons and light. The band model of solids and energy band calculations; the Fermi surface. Transport and optical properties in metals and semiconductors. Magnetism and magnetic resonance; superconductivity. Many-body theory and applications; collective excitations; Green's function techniques in solid state physics.

95-575/576 Neutral Particle Transport **(3-0)(3-0)6**
Prerequisite: Permission of Instructor
Boltzmann and integral transport equations. Spherical harmonic and variational methods, special methods of solving transport equations. Corrections to diffusion theory. Adjoint functions. Applications.

95-581/582 Theory of Noise and Random Processes **(3-0)(3-0)6**
Prerequisite: 95-506, 95—521 concurrently
Probabilities. Statistical analysis of random processes; ensemble theory. Signals and noise in non-linear systems; information theory; normally distributed random processes. Langevin, Fokker-Planck and Boltzmann equations. Thermal, shot and impulse noise. Linear measurements, prediction, and optimum filtering.

95-583/584 General Theory of Relativity **(3-0)(3-0)3**
Prerequisite: Permission of Instructor
Review of Newtonian gravitational theory and special relativity. Principles of equivalence. Tensor analysis in Riemann spaces. Einstein's field equations; tests of Einstein's theory. Spherically symmetric solutions. Applications in astrophysics and cosmology.

95-601 Seminar in Physics **(1-0)(1-0)2**

95-603 Seminar in Nuclear Physics **(1-0)(1-0)2**

95-605/606 Seminar in Solid State Optics **(1-0)(1-0)2**

95-607/608 Seminar in Theoretical Physics **(1-0)(1-0)2**

Individual presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.

95-611/612 Graduate Seminar in Physics **(1-0)(1-0)2**
Presentations by students of research progress.

95-651 Selected Topics in Physics **(3-0)(3-0)6**

95-651/652 Selected Topics in Physics **(3-0)(3-0)6**

95-653/654 Selected Topics in Nuclear Physics **(3-0)(3-0)6**

95-655/656 Selected Topics in Solid State Physics **(3-0)(3-0)6**

95-657/658 Selected Topics in Theoretical Physics **(3-0)(3-0)6**
Recent advances, more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.

95-751/752 Advanced Projects in Physics **(3-0)(3-0)6**
Prerequisite: Permission of Instructor
Independent reading or research not for thesis.

96-701/702 Graduate Research in Physics **(0-9)(0-9)6**
Prerequisite: Departmental approval of a research proposal
Research for M.S. or Ph.D. thesis, or M.S. project.

96-711/712 Special Problems in Physics **(0-9)(0-9)6**
Prerequisite: Permission of Instructor
Reading in preparation for research (in subjects not offered in courses at the time the student wishes to study them), or research not for thesis. If results of the research are subsequently incorporated in a thesis, credits earned in this course may be used to satisfy credit requirements in 95-701, 702, Graduate Research. If results are incorporated in an M.S. project, not more than 3 credits are allowed.

80-506 Nuclear Instrumentation II **(2-4)4**
Prerequisite: 80-202, 24-533
Operating principles and applications of nuclear radiation detectors, associated electronic signal processing equipment, data analysis techniques. Topics covered include charged-particle, photon, and neutron detection, plus charged-particle and gamma-ray spectroscopy. Use of scintillators, photomultiplier tubes, solid state detectors, gas-filled counter, oscilloscopes, etc.

80-539 Electro-Optics **(2-3)4**
Prerequisite: 80-238 or equivalent
Optical properties of materials, including dispersion, absorption, and anisotrophy. Blackbody radiation, emission spectra, incoherent radiators, and lasers. Photoeffect, semiconductor detectors, photochemistry, and applications to various detectors.

80-547 Lasers **(2-3)4**
Prerequisite: 95-335 or equivalent
Interaction of radiation with matter; concept of stimulated emission. Rate equations, optical resonator. Collision and line broadening processes. Study of various lasers, applications to harmonic generation, holography, and optical modulation techniques.

80-551 Fiber Optics (2-3)4

Prerequisite: Permission of Instructor

Introduction to optical communications; basic theory of light guiding; propagation characteristics and focussing effect of an optical waveguide; optical sources and detectors for fiber communications; fundamental parameters of optical fibers, fabrication and testing methods for optical fibers.

80-586 Semiconductors (3-0)3

Prerequisite: 95-472 or equivalent

Transport and optical properties of semiconductors. Statistics, collision mechanisms, and band structure. Hot electrons. High magnetic field phenomena. Devices: junctions and transistors. Gunn oscillators; semiconductor lasers.

RADIOLOGICAL SCIENCES AND PROTECTION

(DEPARTMENT OF PHYSICS)

GRADUATE COORDINATOR: EDWARD L. ALEXANDER, *Professor;* B.S., M.S., University of Maine; Ph.D., Vanderbilt University.

Faculty

George E. Chabot, *Adjunct Professor and University Radiation Safety Officer;* A.B., Harvard University; M.S., Harvard School of Public Health, Ph.D., University of Lowell (C.H.P.).

Clayton S. French, *Lecturer;* B.S., M.S., Ph.D., University of Lowell (C.H.P.)

Jesse Y. Harris, *Professor;* B.S., M.S., Ph.D., Rutgers-The State University.

George B. Inglis, *Adjunct Professor;* B.S., Lowell Technological Institute; M.S., Ph.D., University of Delaware.

Anthony Liuzzi, *Professor,* B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., New York University, (C.H.P.).

Paul J. Ring, *Associate Professor;* B.S., Boston College; M.S., Rensselaer Polytechnic Institute; Ph.D., Brown University.

Kenneth W. Skrable, *Professor;* B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers-The State University (C.H.P.).

Master of Science Degree Program

With the increasing uses of radiation and radioactive materials and the projected increase in the utilization of nuclear power, there will be a growing need for research in Radiological Sciences and Protection. The excellent facilities, equipment and support staff available at the University's Radiation Laboratory and faculty in the Radiological Sciences Program and in other allied departments give students at the University of Lowell a unique opportunity to make significant contributions to research in the radiation protection field.

The Master of Science Degree Program in Radiological Sciences and Protection is interdisciplinary in nature and should be attractive to engineering students and students in the biological and physical sciences. The program is complementary to the Master of Science Degree Program in Environmental Studies, enabling students at the University to pursue careers in all the major areas of environmental protection.

Students are given the opportunity to select programs which respond to the growing manpower needs arising from the increasing use of nuclear energy sources and the increasing uses of radiation and radioactive materials in industry, government, and medicine. For example, the current energy crisis which has resulted from the high level of concern exhibited today regarding the environment has created a critical shortage of professionals needed to perform evaluations of the environmental impact of nuclear reactors and fuel re-processing plants. Through the close alliance of the programs in Radiological Sciences and Protection and in Environmental Studies, students are given the opportunity to obtain education, training, and professional development required for positions in the various employment areas mentioned.

Admission Requirements
A student should have a reasonable preparation including courses in mathematics, chemistry, physics, biology and in nuclear and radiological sciences similiar to the University of Lowell Radiological Health Physics undergraduate curriculum. Since there is no advanced test in the field of Radiological Sciences and Protection, and since various undergraduate backgrounds are suitable for graduate study in the program, students are not required to take the Advanced GRE tests. The GRE Aptitude test, however, is required.

Plan of Study
The program allows a student to select courses and a research project consistent with his/her desired area of professional development. Various opportunities for research and professional development are possible through the use of the Radiation Laboratory of the University and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A research adviser, other than a University of Lowell faculty member, may be approved for the conduct of research at facilities outside the University. A student's program must receive departmental approval. Two M.S. degree options are available: a thesis or a project. In addition to a core curriculum, a satisfactory master's thesis or project is required.

Thesis Option
Under the thesis option, a student must complete a minimum of 21 credits of formal courses and a minimum of 9 credits of graduate research. The master's thesis generally will consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. Proposed research must be approved by the Program Graduate Committee. The format for the final written thesis shall conform to the requirements of the Graduate School. Details of proposal and report requirements may be obtained from the Program Graduate Coordinator.

Project Option
Under the project option, a student must complete a minimum of 27 credits of formal courses and a minimum of 3 credits of graduate project and pass a

comprehensive examination. The master's project consists of a scholarly investigation such as a review, report, design, etc., in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student's adviser in advance. The final report must be approved by the Program Graduate Committee and conform to the format specified by the Graduate School.

Oral Defense of Thesis
A thesis committee is appointed to read a student's thesis and to listen to an oral defense presented by the student. In general, the committee will include the thesis adviser and two additional members chosen from the Radiological Sciences faculty and other departments in which the candidate has taken graduate studies.

Comprehensive Examination for the Project Option
Degree candidates electing the project option are required to pass a Comprehensive written and/or oral examination administered by the Program Graduate Committee. This examination normally will be administered during the semester in which the student completes his course requirements for the M.S. degree. The comprehensive examination may be waived for a student who can document that he/she has passed Part I of the American Board of Health Physics Certification Examination.

Residency Requirements
No residency requirements are specified.

Foreign Language
No language requirements are specified by the Department.

Core Curriculum
A core curriculum consisting of seven courses and research or graduate project in Radiological Sciences and Protection are required of all students pursuing the Master's degree in Radiological Sciences and Protection. These core courses are listed below along with other courses offered by the Department for graduate credit. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies, Biology, Mathematics, Meteorology, Chemistry, and others may be selected for graduate credit with the approval of the Department.

Required Core Courses

24-533	Nuclear Instrumentation I	3
80-505	Nuclear Instrumentation II	4
98-501	Radiation Safety and Control I	4
98-502	Radiation Safety and Control II	4
98-505	Radiation Dosimetry	3
98-532	Introduction to Nuclear Radiation Shielding	3
98-572	Radiation Biology	3
98-601/602	Graduate Project in Radiological Sciences & Protection (Project Option)	3

98-611/612	Graduate Seminar in Radiological Sciences & Protection	2
98-701/702	Graduate Research in Radiological Sciences & Protection (Thesis Option)	9

Five Year B.S./M.S. Degree Program

In recognition of the need for advanced training beyond the Bachelor of Science level in Radiological Sciences, the following represents a program by which outstanding undergraduates can pursue an accelerated five-year course of study leading to the B.S. and M.S. degrees in Radiological Sciences.

1. Undergraduate students who express an interest in this program will be evaluated by the Program Graduate Selection Committee. Those students deemed commendable by the Committee will be advised relative to the correct procedure for successful completion of their B.S. degree, as well as a course of study toward the M.S. degree.

2. The first three years of undergraduate study will be identical to that which is specified for students enrolled in the current four year B.S. program in Radiological Sciences.

3. During the second semester of the junior year and upon approval and recommendation by the Program Graduate Selection Committee, the student will file formal application to the Graduate School. This does not require the student to have taken the GRE examination. The Committee decision will be based on (a) overall grade point average, (b) grade point average in selected subjects, (c) recommendations by Program Faculty, and (d) a one year minimum residency requirement at the University of Lowell. Upon approval and recommendation by the Dean of the Graduate School, the student may be allowed to pursue graduate studies during the senior year and officially become a provisional graduate student in the first semester of the senior year.

4. During the senior year, the student will be permitted to take up to four graduate-level courses which can be applied towards the M.S. degree. Although advanced undergraduate (i.e., 400 level) courses are acceptable, no more than two such courses will be allowed toward the M.S. degree. It should be emphasized that the total number of credits for the combined degrees must be greater than the minimum number of credits required for both the undergraduate and graduate degrees. As an example, the Radiological Sciences Program requires 128 credits and the University B.S. requirement is 120 credits. The student may, with approval, transfer up to 8 credits toward the M.S. degree.

5. Upon completion of the fourth year of study, assuming that all program and university requirements have been met, the student will be awarded the B.S. degree and may then be recommended for full matricula-

tion status by the Program Graduate Selection Committee and the Dean of the Graduate School, prior to the fifth year of study. If the student chooses not to continue toward the M.S. degree (or fails the fifth year), this does not alter receipt of the B.S. degree.

6. Although the options exist for taking an overload in any semester and/or registration for one of more summer sessions, they are not a requirement for this program. However, students wishing to gain a full research experience will be encouraged to initiate their research as early as possible (e.g., during the junior to senior year summer session), which is a distinct advantage of this accelerated program.

7. During the fifth year, as in the standard M.S. degree programs, the student may undertake: (a) thesis option (9 semester hours of Graduate Research), or (b) project option (3 semester hours of Graduate Project). In either case, the student will be required to take two 1-credit Graduate Seminar courses, as well as the other courses required for the M.S. degree in Radiological Sciences, and must satisfy the 30 credit minimum M.S. degree requirement. Upon completion of all Program and Graduate School requirements, the student will be awarded the M.S. degree.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

Objectives

The Applied Physics Concentration is designed to expand the scope of the Ph.D. program in Physics to encompass an option in Radiological Sciences and Protection. It is intended to develop advanced professional and academic competence in practical, applied, technological health physics and to provide professional training for students whose previous specialization need not necessarily have been in the field of physics, but could, e.g., have involved engineering, other science, or mathematical disciplines. For those seeking to pursue careers in education or public service, this program is particularly well-suited.

For physics majors, the acquisition of the doctoral degree would normally require some four years beyond the bachelor's degree or a minimum of two years beyond the master's degree; for non-physics majors, an additional year of study would customarily be entailed.

Course Requirements

At least 60 credit hours are required for the Ph.D. Of these, at least 15 and at most 24, may be for Thesis Research (98-701/702, excluding any credits accepted for 98-701/702 courses in partial fulfillment of the Master's Degree requirements), and at least 30 graduate course credits (with a grade of B or higher), plus at most 3 credits for departmental graduate colloquia and seminars, in addition to 6 credits for the successful compeletion of Advanced Project Research I/II (98-751/752).

A student possessing a Master's Degree for research may apply to have the M.S. thesis or project report accepted in substitution for two semesters of Advanced Project Research I/II (98-751/752).

General Required Courses
Demonstration of competency in the following undergraduate-level physics core courses, or their equivalents, is required (in addition to a comprehensive knowledge of introductory general physics):

95-514 Classical Mechanics
95-535/6 Quantum Mechanics I/II
95-553/4 Electricity and Magnetism I/II

These or their equivalents, would normally be taken (for graduate credit in the case of non-physics majors), when needed, during the first four semesters of the graduate program.

Comprehensive Examination
A comprehensive examination based upon these undergraduate courses will be administered, with the aim of establishing the student's needs in proceeding to graduate-level instruction.

Graduate Level Courses
The required graduate courses comprise:

A. A graduate course in mathematics, such as 95-505/506, Mathematics Methods of Physics or equivalent (3-0)(3-0)6

B. A graduate course in Nuclear Physics, such as 95-561/562 or its equivalent, together with (3-0)(3-0)6

C. At least twelve credits from among the following graduate level Radiological Sciences & Protection courses, assuming that the core courses for the Master of Science Degree in Radiological Sciences and Protection have already been completed:

98-508	Environmental Toxicology & Epidemiology	(3-0)3
98-513	Environmental Monitoring & Surveillance	(3-0)3
98-514	External Radiation Dosimetry	(3-0)3
98-515	Internal Radiation Dosimetry	(3-0)3
98-516	Data Reduction for Rad Sciences & Protection	(3-0)3
98-522	Environmental Radiation & Nuclear Site Criteria	(3-0)3
98-525	Medical Health Physics	(3-0)3
98-546	Accelerator Health Physics	(3-0)3
98-551	Introduction to Electronic Product Radiation	(3-0)3
98-563	Introduction to Radiation Chemistry	(3-0)3

Colloquia and Seminars
Attendance at departmental colloquia or seminars, 95-601/602, and graduate seminars, 98-611/612, each carrying 1 credit per semester, is obligatory in each semester of graduate enrollment. Of the credits so obtained for seminar enrollment, at most 3 credits may be used toward satisfying the graduate credit requirement.

Language Requirement
A demonstration of proficiency adequate for reading technical articles in physics (level two) in French, German, or Russian.

Other Skills
Either (a) a demonstration of reading proficiency (level two) in a foreign language from among French, German or Russian, in addition to that used for the language requirement, or (b) a demonstration of proficiency in computer programming, which may be validated by achieving a grade of B or higher in 92-261, Digital Computer Programming, or 80-397, Computer Programming and Applications I, or by demonstrating equivalent competence to the Physics Department.

Doctoral Research Admission Examination
Ph.D. candidates in the Radiological Sciences and Protection concentration are required to take an oral Doctoral Research Admission Examination after they have satisfactorily completed two semesters (6 credits) of an Advanced Research Project, such as:

98-751/752 Adv. Project in Rad. Scinces I/II (0-10)(0-10)6 cr

or its equivalent, entailing the writing of a comprehensive research report at the conclusion of each of the two semesters in the form of a detailed term paper.

Customarily, non-physics majors would engage in such a research project, which need not necessarily be in the same field as that to be pursued for the Ph.D. thesis research, under the direction of a member of the graduate faculty in their particular area of concentration, during the fifth and sixth semesters of their graduate program, immediately after satisfactory completion of the Comprehensive Examination. The Doctoral Research Admission Examination will concentrate on the material involved in the #751/752 Advanced Research Project and the two research reports (or alternatively, in the case of students who have completed their M.S. degree requirements, on the research and Master's dissertation in their respective field), together with coverage of any topics in satisfactorily completed (with a grade of B or higher) graduate-level courses that the student has taken to date. Upon passing the oral Doctoral Research Admission Examination, the student is eligible to proceed to Ph.D. research, i.e., to submit a Doctoral Research Proposal to the respective Graduate Committee(s), and, if approved, register for:

98-701/702 Graduate Research in Rad Sciences 3, 6, or 9 cr/sem

or equivalent. Of the credits so obtained for #701/702 Thesis Research, a total of at least 15 and at most 24 can be counted toward the required graduate credits.

Thesis Requirements
A thesis proposal must be submitted, according to the procedures in the catalog in the description of the Master of Science Program. A student may not register for 98-701, Graduate Research, until s/he has passed the Ph.D. qualifying examination and his thesis proposal is approved. However, s/he may begin research sooner, and register for 95-711, Special Problems. The thesis is to be based on original research performed under the supervision of a member of the Graduate Faculty holding an earned Ph.D. degree, and written to conform to the requirements of the Graduate School. Four legible copies of a typewritten original must be submitted to the department. Following this, the student must pass an oral examination conducted by his/her thesis committee, based on, but not necessarily limited to, the thesis. If a student wishes to do a thesis under the supervision of a member of the Graduate Faculty of another department or of the University of Lowell Research Foundation, he/she must obtain the consent of the Physics Department.

Typical Schedule in the Radiological Sciences & Protection Option
In conformance with the above requirements, a typical schedule has been drawn up for this option. This may be varied in particular circumstances, and is intended purely for general guidance in compiling a general course of studies for the first six semesters of enrollment in the graduate program.

A TYPICAL SCHEDULE IN THE RADIOLOGICAL SCIENCES & PROTECTION OPTION

Semester I			*Semester II*		
98-501	Radiation Safety & Ctrl	(4)	98-502	Radiation Safety & Ctrl	(4)
98-505	Radiation Dosimetry	(3)	98-532	Intro to Nuc Radiation Shielding	(3)
98-507	Radiation Dosimetry Lab	(1)	98-534	Shielding Laboratory	(1)
98-508	Env Toxicology & Epid	(3)	98-572	Radiation Biology	(3)
98-611	Seminar in Rad Sciences	(1)	98-612	Seminar in Rad Sciences	(1)
	TOTAL	(12)		TOTAL	(12)

Semester III			*Semester IV*		
95-535	Quantum Mechanics I	(3)	95-514	Classical Mechanics	(4)
95-553	Elec. & Magnetism I	(3)	95-536	Quantum Mechanics II	(3)
98-601	Grad Project in Rad Sci	(3)	98-554	Elect. & Magnetism II	(3)
98-611	Seminar in Rad Sciences	(3)	98-612	Seminar in Rad Sci	(1)
	TOTAL	(10)		TOTAL	(11)

Semester V			*Semester VI*		
24-525	Adv Engineering Math	(3)	24-526	Adv Engineering Math	(3)
95-561	Nuclear Physics I	(3)	95-562	Nuclear Physics II	(3)
98-751	Adv Projects Rad Sci I	(3)	98-752	Adv Proj Rad Sci II	(3)
98-611	Seminar in Rad Sciences	(1)	98-612	Seminar in Rad Sci	(1)
	TOTAL	(10)		TOTAL	(11)

Doctoral Research Admission Examination

NOTE: It is assumed that the requirements for the Master of Science degree in Radiological Sciences and Protection will be completed sometime duirng the first four semesters.

Courses of Study

98-501 Principles of Radiation Safety and Control **(3-3)4**
Prerequisite: 80-202 or equivalent
Introduction to radiation protection, including radiation sources, radiation dose and dose measurement, radiation exposure, radiation protection techniques, monitoring methods and instruments, contamination control and waste storage, facility design, hazards analysis, and applied health physics techniques for the safe handling and control of radioactive material, including laboratory.

98-502 Principles of Radiation Safety and Control **(3-3)4**
Prerequisite: 98-501
A laboratory course giving students experience with equipment and practices of current use in the radiation protection field; an extension of 98-501 giving some of the practical aspects of radiation safety and control.

98-505 Radiation Dosimetry **(3-0)3**
Prerequisite: 98-501/502
Sources of radiation exposure; calculations of chronic and acute radiation doses and their effects; internal dosimetry including distribution and elimination of radioisotopes; alpha, beta gamma, and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments including solid state dosimeters, ion chambers, and extrapolation chambers.

98-507 Radiation Dosimetry laboratory **(0-3)1**
Prerequisite: 98-505 currently (not offered every year)
Laboratory experience coordinated with lecture sequence in 98-505.

98-508 Environmental Toxicology and Epidemiology **(3-0)3**
Prerequisite: Graduate student with science background
Study of toxicology and epidemiology of physical and chemical agents including: air pollutants, food additives, ionizing and non-ionizing radiations. Review of current health standards.

98-510 Environmental Toxicology Laboratory **(0-3)1**
Prerequisite: 98-508 concurrently
Laboratory studies of effects of toxic agents on plant and animal systems with emphasis on radiation and air pollutants.

98-513 Environmental Monitoring and Surveillance **(3-0)3**
Prerequisite: 98-502
Sources and types of natural and man-made environmental radioactivity; objectives and design of monitoring programs; strong emphasis on sampling and analytical measurement programs for specific radionuclides and external radiation sources; analytical equipment and procedures and limits of detection for specific radionuclides; design of an environmental laboratory and quality assurance programs for nuclear power stations.

98-514 External Radiation Dosimetry **(3-3)4**
Prerequisite: 98-501/502
Radiation quantities and units; beta, gamma and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments; calibration sources; accident dosimetry; standards and regulatory requirements.

98-515 Internal Radiation Dosimetry **(3-0)3**
Prerequisite: Permission of Instructor
Physiological models for reference man; metabolic models and kinetics; 1959 ICRP 2 and the 1978 ICRP 30 publications; accident internal radiation dosimetry; standards and regulatory requirements.

98-516 Data Reduction for Radiological Sciences and Protection **(3-0)3**
Prerequisite: Permission of Instructor
Fundamental statistical concepts of errors, means, variance and standard deviations of parent and sample populations; permutations and combinations; integral, discrete and differential distribution functions; sampling and counting experiments; propagation of errors; minimum detectable activity and lower limit of detection of counting systems; chi square and other statistical tests of the operability of counting systems; tests of distributions and fitting functions.

98-522 Environmental Radiation and Nuclear Site Criteria **(3-0)3**
Prerequisite: Introductory Course Covering Basic Nuclear Concepts
Study of sources, distribution, environmental transport and dose projections of environmental radionuclides. Emphasis on environmental impact of nuclear fuel cycle.

98-525 Medical Health Physics **(3-0)3**
Prerequisite: 98-501 and 81-252 or equivalent
Sources of radiation and radioactive material associated with the medical applications of nuclear medicine, X-ray diagnosis, and radiation therapy; shielding of X-ray and radiation therapy facilities; survey and monitoring instruments and procedures; personal monitoring; federal and state regulations; waste disposal; and clinical support role of health physicist.

98-532 Introduction to Nuclear Radiation Shielding **(3-0)3**
Prerequisite: Permission of Instructor, Advanced Calculus and Radiological Sciences Graduate Student or equivalent
Interaction of neutrons, gamma rays and charged particles with matter; buildup factors; shielding of point, surface, and volume sources; shielding design factors in reactor and accelerator operations.

98-534 Introduction to Radiation Shielding Laboratory **(0-3)1**
Prerequisite: 98-532 concurrently (not offered every year)
Laboratory coordinated with 98-532 with applications to health physics problems.

98-541 Radiosotope Techniques (3-0)3

Prerequisite: Undergraduate background in sciences or engineering or equivalent math and physics preparation

Study of the theory and use of radionuclides as tracers and the principles of operation of radiation counting systems.

98-543 Radioisotope Techniques Laboratory (0-3)1

Prerequisite: 98-541 concurrently

Laboratory experience in tracer techniques including use of GM, proportional, and various scintillation systems for counting alpha, beta, and gamma radiations. Applications in chemistry and biology.

98-546 Accelerator Health Physics (3-0)3

Prerequisite: 98-501/502

Health physics problems common to particle accelerator facilties are presented with discussions of current approaches to their solutions. Estimation of the levels of induced radioactivity expected and calculations of shielding and ventilation requirements will be made for a variety of particle accelerators.

98-551 Introduction to Electronic Product Radiation (3-0)3

Prerequisite: 98-501

The theoretical and applied aspects of the generation, measurement, and uses of radiant energy from electronic products whose emissions span the entire electromagnetic spectrum; ultrasonic energy emitted by electronic products, biological effects, standards of protection and control, and consequences and intent of Public Law 90-602.

98-561/562 Special Topics in Radiological Sciences (3-0)3

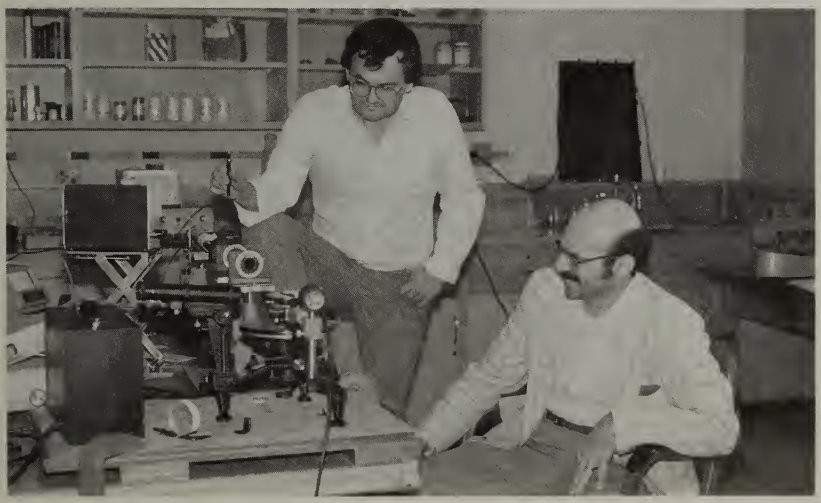
Prerequisite: Radiological Sciences and Protection Graduate Student

This course is used to provide students with current information on topics of interest to graduate students in Radiological Sciences and Protection. Course may include preparation and presentation of lectures applicable to training of health physics technicians. Topics covered may vary from year to year. Topics are announced prior to registration.

98-563 Introduction to Radiation Chemistry (3-0)3

Prerequisite: Permission of Instructor (not offered every year)

A study of the interaction of all types of ionizing radiation with matter and the resulting radiation-induced chemical reactions; excitation, ionization, and free radical formation and recombination.



98-572 Radiation Biology **(3-0)3**

Prerequisite: Introductory nuclear course and course in human physiology

Study of biological effects and mechanisms of action of ionizing radiations from subcellular through whole organism and ecological levels.

98-601/602 Graduate Project in Radiological Sciences and Protection **(0-10)3**

Prerequisite: Completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of faculty advisor.

This course provides credit for a project done by Master's degree candidates.

98-611/612 Graduate Seminar in Radiological Sciences and Protection **(1-0)1**

Individual presentations by students and staff of advanced topics, original research or journal articles. Given when the demand is sufficient.

98-701/702 Graduate Research in Radiological Sciences and Protection **(0-10)3**

Prerequisite: Completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of faculty adviser.

This course provides credit for thesis research done by master's degree candidates.

98-751/752 Advanced Projects in Radiological Sciences and Protection **(0-10)1-3**

An opportunity for individual study under the direction of a staff member of topics related to Radiological Sciences and Protection.

99-561/562 Special Topics in Radiological Sciences and Protection **(1-3,0)1-3**

This course is used to provide non-major students with current information on a variety of topics in Radiological Sciences. Topics covered are announced prior to registration. May not be credited to Radiological Sciences and Protection major.

CADEMIC CALENDAR 1985-1986

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	August 28-29
Classes Begin	September 3
Last Day to Change Enrollment Status (i.e, add, drop courses, etc.)	September 16
Last Day for Clearance Forms for Summer Degree	September 27
Columbus Day - University Closed	October 14
Advising Period for Spring Registration	November 4-15
Veteran's Day - University Closed	November 11
Thanksgiving Recess Begins - 6:00 pm	November 27
Classes Resume	December 2
Registration for Spring Semester	December 2, 3
Last Day to Drop Classes with W	December 6
Classes End	December 13
Final Examinations Begin	December 14
Last Day of Final Examinations - Semester Ends	December 20
Last Day to Submit Clearance Forms for Fall Degree	December 20

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 15-16
Classes Begin	January 21
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 3
Washington's Birthday - University Closed	February 17
Spring Recess Begins	March 14
Classes Resume	March 24
Advising Period for Fall Registration	April 2-11
Registration for Fall Semester	April 28-29
Last Day for Students to Drop Course with W	May 1
Classes End	May 8
Final Examinations Begin	May 9
Last Day to Submit Clearance Forms for Spring Degree	May 9
Last Day of Final Examinations - Semester Ends	May 17
Commencement	May 31

ACADEMIC CALENDAR 1986-1987

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	August 27-28
Classes Begin	September 2
Last Day to Change Enrollment Status (i.e, add, drop courses, etc.)	September 15
Last Day for Clearance Forms for Summer Degree	September 26
Columbus Day - University Closed	October 15
Veteran's Day - University Closed	November 11
Advising Period for Spring Registration	November 17-26
Thanksgiving Recess Begins - 6:00 pm	November 26
Classes Resume	December 1
Registration for Spring Semester	December 1-2
Last Day to Drop Classes with W	December 5
Classes End	December 12
Final Examinations Begin	December 13
Last Day of Final Examinations - Semester Ends	December 22
Last Day to Submit Clearance Forms for Fall Degree	December 22

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 15-16
Classes Begin	January 20
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 2
Washington's Birthday - University Closed	February 16
Spring Recess Begins	March 13
Classes Resume	March 24
Advising Period for Fall Registration	April 1-17
Patriot's Day	April 20
Monday Schedule on Wednesday	April 22
Last Day for Students to Drop Course with W	April 24
Registration for Fall Semester	April 27-28
University Day (Spring Carnival) - No Classes	May 1
Classes End	May 7
Final Examinations Begin	May 8
Last Day to Submit Clearance Forms for Spring Degree	May 8
Last Day of Final Examinations - Semester Ends	May 16
Commencement	May 30

ACADEMIC CALENDAR 1987-1988

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	September 2-3
Classes Begin	September 7
Last Day to Change Enrollment Status (i.e, add, drop courses, etc.)	September 14
Last Day for Clearance Forms for Summer Degree	September 25
Columbus Day - University Closed	October 12
Advising Period for Spring Registration	November 5-16
Registration for Spring Semester	November 19-20
Thanksgiving Recess Begins - 6:00 pm	November 25
Classes Resume	November 30
Last Day to Drop Classes with W	December 4
Classes End	December 11
Final Examinations Begin	December 12
Last Day of Final Examinations - Semester Ends	December 20
Last Day to Submit Clearance Forms for Fall Degree	December 20

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 13-14
Classes Begin	January 19
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 1
Spring Recess Begins	March 11
Classes Resume	March 21
Advising Period for Fall Registration	April 4-15
Registration for Fall Semester	April 25-26
Last Day for Students to Drop Course with W	April 29
Classes End	May 5
Final Examinations Begin	May 6
Last Day to Submit Clearance Forms for Spring Degree	May 6
Last Day of Final Examinations - Semester Ends	May 14
Commencement	May 28

STATEMENT ON ACADEMIC HONESTY

It is the expressed policy of the University of Lowell that Graduate Academic life related to the University will be conducted in an honest and uncompromising manner by the graduate students and faculty.

Apparent and all alledged breeches of this policy will be dealt with by the Graduate Academic Policy Committee in accordance with the procedure delineated in the graduate appeals process.

DEFINITION OF ACADEMIC DISHONESTY

The following definitions are provided for the information of all students and constitute official notice of prohibited academic practice and behavior.

Cheating is defined as (1) misrepresenting academic work which has been done by another as one's own efforts - whether such misrepresentation has been accomplished with or without the permission of the other individual; (2) utilization of prohibited assistance (whether in the nature of a person or a resource) in the performance of assignments and examinations; (3) copying of another person's work or the giving or receiving of information or answers by any means of communication during an examination; (4) utilization of the services of a commercial term paper company; and (5) *the unauthorized or fraudulent acquisition and or use of another's academic property.*

Plagiarism is defined as direct quotation or word-for-word copying of all or part of the work of another without identification or acknowledgement of the quoted work; (2) extensive use of acknowledged quotation from the work of others which is joined together by a few words or lines of one's own text; and (3) an abbreviated restatement of someone else's analysis or conclusion, however skillfully paraphrased.

UNIVERSITY APPEALS REGARDING ACADEMIC ISSUES OF GRADUATE STUDENTS

The underlying purpose of University Appeal procedures is to guarantee due process and protect the rights of students and faculty in our graduate programs. The University recognizes the necessity for procedures to deal with academic matters and the need for faculty and student input for such issues. The following procedure is designed to provide a mechanism for adjudication of academic issues that may arise from time to time.

The primary resolution of academic appeals of students should be within the department. The first step in the resolution of a problem should be an informal discussion with a student's faculty advisor or the coordinator of the program.

If the matter cannot be resolved after such a discussion, a formal appeal, in writing, should be presented to the Department or Area Graduate Academic Policy Committee. Within seven working days the committee shall convene and discuss the appeal with the student. The student may be accompanied by his advisor or a faculty representative during the discussion of the appeal. The committee, by a majority vote, shall render a decision within five working days and notify the appropriate parties in writing with the rationale for the decision included in the notification.

If the decision is not satisfactory to all parties involved, the appeal may proceed to the Departmental or Area graduate faculty. The faculty shall convene within seven working days and discuss the matter with the student and faculty advisor or representative. The faculty, by a majority vote, shall render a decision within five working days and notify the appropriate parties in writing with the rationale for the decision included in the notification.

If the decision is not satisfactory to all parties, the appeal may be forwarded to a college committee composed of area coordinators of all programs within the college*. Within seven working days the committee shall convene and discuss the appeal with the student. At this level the student may request that discussions or proceedings with the student present be taped and that a transcript be prepared from the tape. The request for recording must be made at the time the appeal is made to the college committee. The committee shall render a decision within 5 working days and notify the appropriate parties with the rationale for the decision included in the notification.

If the decision is not satisfactory to all parties, the appeal may be forwarded to the Graduate Academic Policy and Curriculum Committee. The committee shall convene within 10 working days and discuss the appeal with the student and faculty advisor or representative. A request for recording and preparing a transcript of the discussions with the student

*In colleges with less than three coordinators, the appeal may proceed directly to the next level.

present may be made at the time of appeal. The committee shall render a decision within 5 working days and notify the appropriate parties. The decision of the Graduate Academic Policy Committee shall be final and the informaion accummulated during the appeal procedure shall be forwarded to the Dean of the Graduate School to be kept on file. If any decision involving the awarding of a degree is made and the official deadline for graduation exercises has passed during the appeal, the degree date will reflect the initiation of the appeal. It is assumed that the notification of appropriate parties shall include the Dean of the Graduate School and Coordinator of the program involved.

UNIVERSITY DISCIPLINARY PROCEDURES FOR GRADUATE STUDENTS

The underlying purpose of University disciplinary procedures is educational. Such procedures accordingly seek to promote the achievement to self-discipline and self-direction on the part of the student by fostering personal responsibility and accountability. In the administration of these procedures, the University recognizes the legitimate concern of the student body, the faculty, and the administration and is committed to a proper balance between protection for the individual and the academic community. In the imposition of disciplinary penalties, the University makes every effort to avoid dual punishment of an offender for the same wrongful act and therefore refrains from disciplinary action when sufficient disposition of an offense has been made by a court of law. Unlawful acts and acts of misconduct which are committed off campus are not the responsibility of the University and are not subject to adjudication by University procedures.

The Role of the Dean of the Graduate School:
All complaints concerning student misconduct or charges concerning violation of administrative requirements of the University must be forwarded in writing to the Dean of the Graduate School who, within a reasonable time thereafter, shall provide the student with the name of the complainant, a copy of the charges filed, and a statement of hearing procedures and individual rights of due process. Within 5 academic days of this notification, the Dean of the Graduate School shall schedule a personal interview with the student, at which time the student may explain the circumstances of the complaint or charge and/or may affirm the charges or complaint as filed, may call witnesses on his or her behalf, and may confront and question those who appear to give testimony. Within a week of this interview, the Dean of the Graduate School shall render a decision concerning the complaint or charge filed and shall forward a copy of his decision to the student and complainant by certified or registered letter, return receipt requested. In the event that the dean has specified a sanction, his letter shall notify the student of his or her right to appeal the decision to a Board of Appeals and to be represented and/or assisted by a faculty adviser in making such an appeal.

The Dean of the Graduate School shall have authority to impose a sanction without recourse by the student to subsequent hearings if the student has failed to report for a personal interview as scheduled and has not been excused from reporting for good and sufficient reason. If a student against whom a sanction has been imposed makes no appeal to a Board of Appeals, the punishment determined by the Dean of the Graduate School shall be implemented within 10 days. Pending action on an appeal of sanction imposed by the Dean of the Graduate School, the status of a student shall not be altered and his or her right to be present on campus and to attend classes shall not be suspended unless, in the opinion of the Dean of the Graduate School and the Vice President for Student Affairs, failure to implement such sanction may reasonably pose a threat to the safety of persons or the protection of University property.

The Composition and Role of the Board of Appeals:

The Board of Appeals shall consist of two graduate faculty members appointed by the Chairperson of the Graduate Faculty, two members appointed by the Chairperson of the Graduate Faculty, two administration members appointed by the Vice President for Student Affairs, and three graduate student members appointed by majority vote of the Graduate Student Senate. An alternate shall be appointed respectively by the Chairperson of the Graduate Faculty, the Vice President for Student Affairs, and the Graduate Student Senate for each regular member designated. Upon written notification to the Board at least two days prior to a scheduled hearing, the student defendant or the Dean of the Graduate School each has the right to remove, without cause, one regular member of the Board and to replace such member with his or her designated alternate. The Board shall elect a person from among its members who shall conduct the hearing and who shall assume responsibility for assuring an accurate record of the hearing.

An official record of the hearing, including a record of testimony, shall be made by a duly appointed stenographer or by tape recorder. The transcript or tape recording shall be for the use of the Board only, and upon the conclusion of the hearing it shall be deposited with the Vice President for Student Affairs, who shall subsequently release this record only upon the direction of the President or upon the order of a court of competent jurisdiction. Upon the student's graduation or withdrawal from the University, a *copy* of the official record of the student's hearing may be released to the student when such release has been approved by the University President. The original transcript will be kept in the office of the Vice President for Student Affairs.

The Board of Appeals shall receive a written charge from the Dean of the Graduate School which provides the name of the accused student and the specific allegation of student misconduct. A copy of such charge shall be conveyed to the student by the Board, together with a notice of time and place of official hearing before the Board. The student may be assisted in his or her defense by a graduate faculty adviser and/or legal counsel of his or her choice, may present evidence,and may call witnesses in his or her defense. Hearings before the Board of Appeals shall be private unless the

student has filed a written request for a public hearing with the Board at least two days prior to the scheduled hearing date.

Attendance at Hearings of the Board of Appeals:

The following individuals shall have a right to be in attendance at a hearing of the Board of Appeals: the Dean of the Graduate School, the student defendant, the student's graduate faculty adviser, and/or legal counsel, the complainant and the legal counsel of the Board of Trustees. Individuals other than those enumerated above who have a direct interest in the proceedings may be permitted to attend at the discretion of the Board. The Board may revoke such permission at any time during the course of a hearing. A decision to permit an individual's attendance or to revoke such permission shall require a five/seven majority vote of the Board.

Admissibility of Evidence:

Decisions of the Board of Appeals shall be based solely upon evidence which has been introduced during official Board hearings. Improperly acquired evidence shall not be admitted before the Board. In any proceeding, the admissibility of evidence shall be governed by the Rules of Evidence which are specified by Chapter 30 A of the General Laws (State Administrative Procedure Act) concerning adjudication. Information pertaining to the defendant's academic standing or to his or her previous record of offenses shall be introduced in hearing only if the Board deems such information to be relevant. Each witness testifying during a Board hearing shall be called into the hearing room at the time he or she is to testify and shall leave the hearing room immediately after providing testimony. Members of the Board, the student defendant, the defendant's graduate faculty adviser, and the Dean of the Graduate School may question any witness concerning his or her testimony.

Powers of the Board of Appeals:

The legal counsel for the Board of Trustees shall be the legal adviser to the Board of Appeals. By an affirmative vote of five/seven, the Board of Appeals may affirm, reverse, increase, or decrease a sanction which has been imposed by the Dean of the Graduate School. Upon the conclusion of each hearing, and within 10 working days the Board shall forward a written statement of its decision, signed by all Board members, to the President of the University, the student defendant, the complainant, and the Dean of the Graduate School. All decisions of the Board of Appeals shall be implemented on the third academic day (including summer sessions) following the date of Board notification to the student defendant unless the Dean of the Graduate School or the student defendant notifies the Board in writing of his or her decision to appeal the Board's decision to the President of the University.

APPEAL TO THE PRESIDENT OF THE UNIVERSITY

An appeal to the President of the University may be initiated by the Dean of the Graduate School or the student defendant and must be made in

writing to the Vice President for Student Affairs within two academic days following notification by the Board of Appeals. The President's review shall be based on the complaint, the decision of the Dean of the Graduate School, the record of the hearing, and the decision of the Board of Appeals. The decision of the President shall be implemented within 10 days following the date of presidential notification to the student defendant unless the student defendant notifies the President in writing of his or her decision to appeal the President's decision to the Student Affairs Committee of the Board of Trustees. In the event that the President alters the decision rendered by the Board of Appeals, he shall provide a written statement of his decision, together with his reasons, to the Board of Appeals.

APPEAL TO THE BOARD OF TRUSTEES

A student defendant has a right to appeal the decision of the President to the Student Affairs Committee of the Board of Trustees. This appeal must be made in writing to the Vice President for Student Affairs within two academic days following the date of presidential notification to the student defendant. All decisions of the Student Affairs Committee of the Board of Trustees are final and shall be implemented with 10 days.

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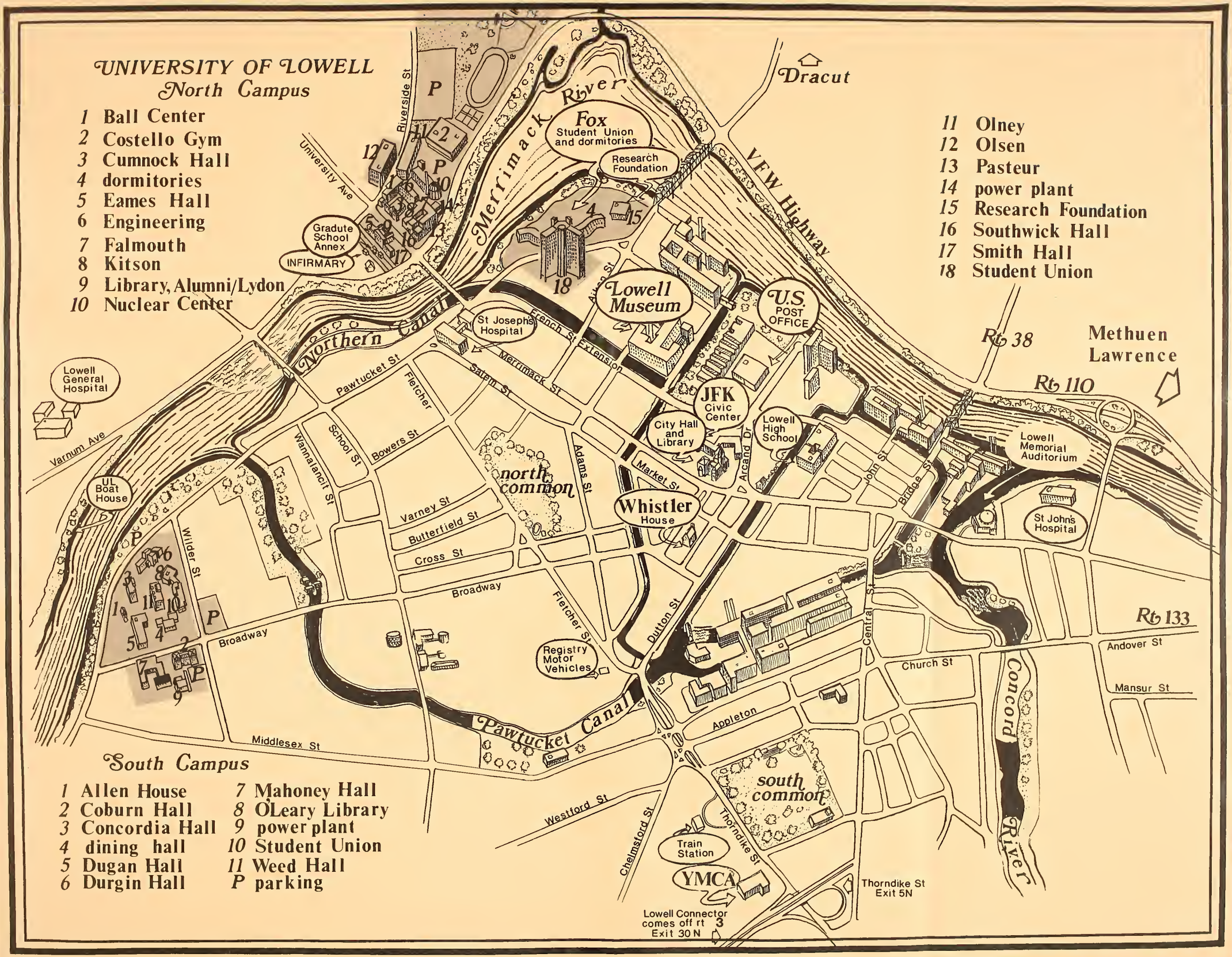
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North Campus
1 Ball Center
2 Costello Gym
3 Cumnock Hall
4 dormitories
5 Eames Hall
6 Engineering
7 Falmouth
8 Kitson
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10 Nuclear Center
11 Olney
12 Olsen
13 Pasteur
14 power plant
15 Research Foundation
16 Southwick Hall
17 Smith Hall
18 Student Union
Dracut
Merrimack River
Riverside St
University Ave
Fox Student Union and dormitories
Research Foundation
VFW Highway
Gradute School Annex
INFIRMARY
Lowell Museum
U.S. POST OFFICE
Rt 38
Methuen
Lawrence
Rt 110
St Joseph's Hospital
French St Extension
Northern Canal
Merrimack St
Salem St
Pawtucket St
Fletcher
Lowell General Hospital
Varnum Ave
JFK Civic Center
City Hall and Library
Lowell High School
Lowell Memorial Auditorium
St John's Hospital
School St
Bowers St
Wannalancit St
north common
Adams St
Market St
Arcand Dr
John St
Bridge St
Whistler House
UL Boat House
Wilder St
Varney St
Butterfield St
Cross St
Broadway
Fletcher St
Dutton St
Central St
Rt 133
Registry Motor Vehicles
Church St
Andover St
Mansur St
Concord River
Pawtucket Canal
Middlesex St
Appleton
south common
Westford St
Chelmsford St
Thorndike St
Train Station
YMCA
Thorndike St Exit 5N
Lowell Connector comes off rt 3 Exit 30 N
South Campus
1 Allen House
2 Coburn Hall
3 Concordia Hall
4 dining hall
5 Dugan Hall
6 Durgin Hall
7 Mahoney Hall
8 O'Leary Library
9 power plant
10 Student Union
11 Weed Hall
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